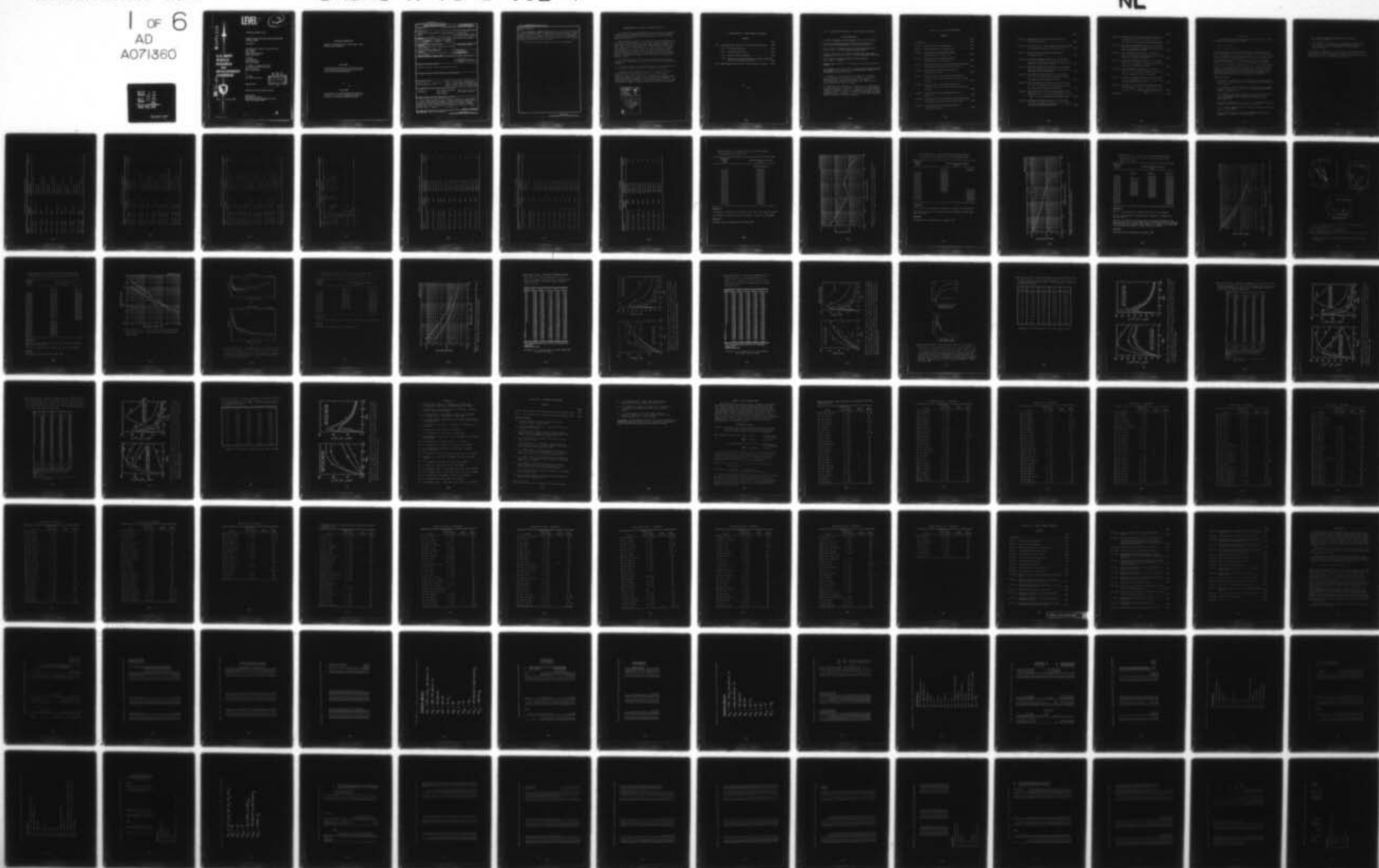
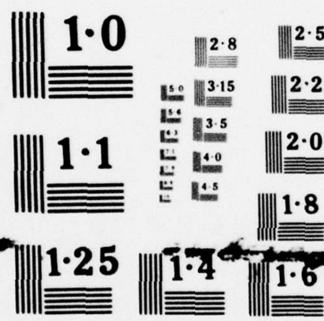
AD-A071 360 ARMY MISSILE RESEARCH AND DEVELOPMENT COMMAND REDSTO--ETC F/G 20/5
COMPILATION OF DATA RELEVANT TO NUCLEAR PUMPED LASERS. VOLUME I--ETC(U)
DEC 78 E W MCDANIEL, M R FLANNERY, E W THOMAS

UNCLASSIFIED DRDMI-H-78-1-VOL-4 NL

1 OF 6
AD
A071360





NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

LEVEL III

B.S.

2

AD A071360

U.S. ARMY
MISSILE
RESEARCH
AND
DEVELOPMENT
COMMAND

Redstone Arsenal, Alabama 35809

TECHNICAL REPORT H-78-1

COMPILATION OF DATA RELEVANT TO NUCLEAR PUMPED LASERS

VOLUME IV

E. W. McDaniel, M. R. Flannery, E. W. Thomas, H. W. Ellis
and K. J. McCann
School of Physics
Georgia Institute of Technology
Atlanta, Georgia 30332

S. T. Manson
Physics Department
Georgia State University
Atlanta, Georgia 30303

J. W. Gallagher, J. R. Rumble, and E. C. Beaty
Joint Institute for Laboratory Astrophysics
University of Colorado
Boulder, Colorado 80302

and

T. G. Roberts
High Energy Laser Laboratory

December 1978

Approved for public release; distribution unlimited

PREPARED FOR:
High Energy Laser Laboratory
US Army Missile Research and Development Command
Redstone Arsenal, Alabama 35809

DISPOSITION INSTRUCTIONS

DESTROY THIS REPORT WHEN IT IS NO LONGER NEEDED. DO NOT RETURN IT TO THE ORIGINATOR.

DISCLAIMER

THE FINDINGS IN THIS REPORT ARE NOT TO BE CONSTRUED AS AN OFFICIAL DEPARTMENT OF THE ARMY POSITION UNLESS SO DESIGNATED BY OTHER AUTHORIZED DOCUMENTS.

TRADE NAMES

USE OF TRADE NAMES OR MANUFACTURERS IN THIS REPORT DOES NOT CONSTITUTE AN OFFICIAL INDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL HARDWARE OR SOFTWARE.

14 DRDMI-H-78-1-VOL-4

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER H-78-1	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) COMPILATION OF DATA RELEVANT TO NUCLEAR PUMPED LASERS Volume II. A053827		5. TYPE OF REPORT & PERIOD COVERED Technical Data
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) E. W. McDaniel, M. R. Flannery, E. W. Thomas, H. W. Ellis, ~~and~~ K. J. McCann, S. T. Manson, J. W. Gallagher, J. R. Rumble, E. C. Beaty, and T. G. Roberts		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Commander US Army Missile Research and Development Command Attn: DRDMI-H Redstone Arsenal, Alabama 35809		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 12 573p.
11. CONTROLLING OFFICE NAME AND ADDRESS Commander US Army Missile Research and Development Command Attn: DRDMI-TI Redstone Arnsenal, Alabama 35809		12. REPORT DATE December 1978
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

*Present Address: Eckerd College, St. Petersburg, FL 33733

Volume I contains pages 1 through 427;
Volume II contains pages 429 through 892;
Volume III contains pages 893 through 1348;
Volume IV contains pages 1349 through 1916

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Excitation	Laser pumping mechanisms	High energy electron beams
Ionization	Heavy nuclides	High energy ion beams
	Light nuclides	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This volume and Volumes III and V contain a compilation of data relevant to nuclear pumped lasers and are part of a series on atomic and molecular data for gas laser research and development. The first two volumes, contained "Compliation of Data Relevant to Rare Gas-Rare Gas and Rare Gas-Monohalide Excimer Lasers" by E. W. McDaniel, M. R. Flannery, H. W. Ellis, F. L. Eisele, W. Pope, and T. G. Roberts.

next page

ABSTRACT (CONTINUED)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

410 127

JOB

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

ABSTRACT (CONCLUDED)

Volumes ~~III and~~ IV ~~(presented here)~~ contain data on many different species on atoms, molecules, and ions: a large fraction of them are already of direct interest in laser media; many more may become important in the future. These volumes cover all of the subjects treated in Vols. I and II; one difference is that now secondary electron energy sepctra are discussed in a separate chapter. A chapter on nuclear data has also been added.

A species index for all five volumes will be published separately.

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

ACKNOWLEDGMENTS FOR VOLUME IV (CHAPTERS B AND C)

It is a pleasure to acknowledge the help of Dr. Daniel L. Albritton of NOAA, Boulder, Colorado, who permitted access to his compliation of ion-molecule reaction rates before its publication. Many of his data appear in Section B-1.B.

Special thanks are due Dr. C. F. Barnett, of the Oak Ridge National Laboratory, for permission to use many of his drawings in Chapter B. These figures can be identified by their ORNL number appearing at their upper right. They originally appeared in "Atomic Data for Controlled Fusion Research", by C. F. Barnett, J. A. Ray, E. Ricci, M. I. Wilker, E. W. McDaniel, E. W. Thomas, and H. B. Gilbody; ORNL-5206 and 5207. Oak Ridge National Laboratory, Oak Ridge, Tennessee (February 1977). These two volumes are available from the National Technical Information Service, US Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

Dr. David Garvin and Dr. Robert Hampson of the National Bureau of Standards were very helpful in supplying bibliographies on heavy particle reactions.

Dr. Fred L. Eisele of the Georgia Institute of Technology did much of the work on Section B-1.D, and we are grateful for his help.

The authors wish to thank Dr. A. V. Phelps of JILA for helpful discussions in the preparation of Chapter C. Gratitude is also expressed to Drs. Sydney Geltman, D. W. Norcross, D. G. Hummer. Thanks are given to the staff of the JILA Information Center Who helped collect and assemble the material: Greg Klingler, Doug McCampbell, Patti Krog, and Pat Ruttenberg. We are also grateful to Dr. S. F. Wong, who provided a number of figures showing data on electron collisions.

B. HEAVY PARTICLE — HEAVY PARTICLE COLLISIONS

CONTENTS

B-1. LOW ENERGY HEAVY PARTICLE — HEAVY PARTICLE COLLISIONS

General References

1. G. Bekefi, Principles of Laser Plasmas, Wiley, New York (1976).

2. J. B. Hasted, Physics of Atomic Collisions (Second Edition), American Elsevier Publishing Co., Inc., New York (1972).

3. H. S. W. Massey, Electronic and Ionic Impact Phenomena (Second Edition), Vol. III, Oxford University Press (1971).

4. H. S. W. Massey and H. B. Gilbody, Electronic and Ionic Impact Phenomena (Second Edition), Vol. IV, Oxford University Press (1974).

5. E. W. McDaniel, Collision Phenomena in Ionized Gases, Wiley, New York, (1964).

6. Excimer Lasers, (Edited by C. K. Rhodes), Springer-Verlag, Berlin (1979).

7. M. H. Bortner and T. Baurer (Eds.), "Defense Nuclear Agency Reaction Rate Handbook" (Second Edition), DNA 1948-H (1972). Also see supplements published since 1972.

8. C. F. Barnett, J. A. Ray, E. Ricci, I. Wilker, E. W. McDaniel, E. W. Thomas and H. B. Gilbody, "Atomic Data for Controlled Fusion Research," Controlled Fusion Atomic Data Center, Oak Ridge National Laboratory, Oak Ridge, Tenn. (February 1977). Reports ORNL 5206 and 5207, 680 pages.

9. C. F. Barnett, E. W. McDaniel, E. W. Thomas, et al., "Bibliography of Atomic and Molecular Processes" (1950-1978), Oak Ridge National Laboratory, Oak Ridge, Tennessee. Categorized according to kind of collision, process, or property. Information concerning procurement available from C. F. Barnett, P. O. Box X, Building 6003, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Section B-1.A. ION-ION RECOMBINATION

CONTENTS

Page

Page

Introduction

The processes of interest here are the two- and three-body mechanisms which may respectively be written:

$$X^+ + Y^- \rightarrow [X + Y]$$

$$X^+ + Y^- + Z \rightarrow [X + Y] + Z$$

The square brackets indicate that the species may remain associated after recombination. They may also be excited. Data for the two-body case are presented as a two-body rate in units of $cm^3\ s^{-1}$. Data for the three-body case are normally presented in the form of a two-body rate for recombination ($cm^3\ s^{-1}$) as a function of the total gas density; density is often expressed as the ratio N/N_L where N is the density (cm^{-3}) and N_L is Loschmidt's number ($2.69 \times 10^{19}\ cm^{-3}$, the number density at STP). In the following tabular presentations a reaction is identified by the recombining ions but the final state of the atoms is not indicated unless the author of the original data has done so; in most experimental measurements only the loss of ions by recombination is monitored and the final state of the products is not defined.

General References:

1. D. R. Bates, "Recombination", in "Case Studies in Atomic Physics" (Edited by E. W. McDaniel and M. R. C. McDowell), 4, 59, North-Holland, Amsterdam (1975).

2. M. R. Flannery, "Ionic Recombination", "Atomic Processes and Applications", (Edited by P. G. Burke and B. L. Moiseiwitsch), North-Holland, Amsterdam (1976).

3. M. R. Flannery, "Three-Body Recombination of Positive and Negative Ions", "Case Studies in Atomic Collision Physics" (Edited by E. W. McDaniel and M. R. C. McDowell), 2, 3, North-Holland, Amsterdam (1972).

4. B. H. Mahan, "Recombination of Gaseous Ions," Advances in Chemical Physics, (Edited by I. Prigogine), 23, 1, (1973).

5. H. S. W. Massey, Negative Ions (Third Edition), Cambridge University Press, New York (1976).

6. H. S. W. Massey and H. B. Gilbody, Electronic and Ionic Impact Phenomena, 4, Clarendon Press, Oxford (1974).

7. E. W. McDaniel, Collision Phenomena in Ionized Gases, Wiley, New York (1964).

8. J. T. Moseley, R. E. Olson, and J. R. Peterson, "Ion-Ion Mutual Neutralization," Case Studies in Atomic Physics (Edited by E. W. McDaniel and M. R. C. McDowell), 5, 1, North-Holland, Amsterdam (1976).

Data Needed: Experimental rate coefficients for three-body recombination in pure gases and gas mixtures at high pressures with positive identification of the recombining ionic species. "High pressure" means pressures from 1 Torr to the highest possible value.

Tabular Data B-1.A-1. Two-body reactions.

Reaction	Temperature or Energy	Cross Section or Reaction Rate	Reference
$H^+ + H^- \rightarrow H + H$	300^oK	$3.9 \pm 2.1 \times 10^{-7}$ cm^3 s^{-1}	1
$H^+ + H^- \rightarrow H + H$	10^{-1} to 10^4 eV	Table B-1.A-3 Graph B-1.A-4	2
$He^+ + H^- \rightarrow He + H$	300^oK	5.7 to 7.3×10^{-7} cm^3 s^{-1} (theoretical estimate)	1
$He^+ + H^- \rightarrow He + H$	1 to 500 eV	Table B-1.A-5 Graph B-1.A-6	3
$He^+ + D^- \rightarrow He + D$	300^oK	4.5 to 5.7×10^{-7} cm^3 s^{-1} (theoretical estimate)	1
$He^+ + D^- \rightarrow He + D$	500 to 6000 eV	Table B-1.A-5 Graph B-1.A-6	3
$N^+ + O^- \rightarrow$ Unspec.	300^oK	$2.6 \pm 0.8 \times 10^{-7}$ cm^3 s^{-1}	1
$N^+ + O^- \rightarrow$ Unspec.	0.1 to 15 eV	Table B-1.A-7 Graph B-2.A-8	1
$O^+ + O^- \rightarrow$ Unspec.	300^oK	$2.7 \pm 1.3 \times 10^{-7}$ cm^3 s^{-1}	1
$O^+ + O^- \rightarrow$ Unspec.	0.1 to 20 eV	Table B-1.A-7 Graph B-1.A-8	1
$Ne^{+*} + F^- \rightarrow Ne\ F^*$	300^oK	1.0×10^{-6} cm^3 s^{-1}	4
$Na^+ + O^- \rightarrow$ Unspec.	300^oK	$2.1 \pm 1.0 \times 10^{-7}$ cm^3 s^{-1}	1

Tabular Data B-1.A-1. (Continued).

Reaction	Temperature or Energy	Cross Section or Reaction Rate	Reference
$Na^+ + O^- \rightarrow$ Unspec.	0.15 to 15 eV	Graph B-1.A-9	1, 5
$Na^+ + O^- \rightarrow Na^* + O$	0.1 to 7 eV	Graph B-1 A-9	6
$Xe^{+*} + F^- \rightarrow Xe\ F^*$	300^oK	$1.0 \times 10^{-6}\ cm^3\ s^{-1}$	4
$H_2^+ + D^- \rightarrow$ Unspec.	300^oK	$4.7 \pm 1.5 \times 10^{-7}\ cm^3\ s^{-1}$	1
$H_2^+ + D^- \rightarrow$ Unspec.	0.1 to 60 eV	Table B-1.A-7 Graph B-1.A-8	1
$N_2^+ + O^- \rightarrow$ Unspec.	300^oK	$2.0 \pm 0.6 \times 10^{-7}\ cm^3\ s^{-1}$ (theoretical estimate)	1
$N_2^+ + O_2^- \rightarrow$ Unspec.	300^oK	$1.6 \pm 0.5 \times 10^{-7}\ cm^3\ s^{-1}$	1
$N_2^+ + O_2^- \rightarrow$ Unspec.	0.15 to 90 eV	Table B-1.A-10 Graph B-1.A-11	1
$N_2^+ + NO_2^- \rightarrow$ Unspec.	300^oK	$1.3 \pm 0.5 \times 10^{-7}\ cm^3\ s^{-1}$	1
$NO^+ + O^- \rightarrow$ Unspec.	300^oK	$4.9 \pm 2.0 \times 10^{-7}\ cm^3\ s^{-1}$	1
$NO^+ + O_2^- \rightarrow$ Unspec.	300^oK	$5.8 \pm 1.0 \times 10^{-7}\ cm^3\ s^{-1}$	1
$NO^+ + O_2^- \rightarrow$ Unspec.	0.15 to 100 eV	Values essentially equal to those for $O_2^+ + O_2^-$ shown in B-1.A-10 and B-1.A-11	1
$NO^+ + NO_2^- \rightarrow$ Unspec.	300^oK	$5.1 \times 10^{-7}\ cm^3\ s^{-1}$	7
$NO^+ + NO_2^- \rightarrow$ Unspec.	300^oK	$6.4 \pm 0.7 \times 10^{-8}\ cm^3\ s^{-1}$	8
$NO^+ + NO_2^- \rightarrow$ Unspec.	300^oK	$5.1 \pm 1.5 \times 10^{-7}\ cm^3\ s^{-1}$	1

Tabular Data B-1.A-1. (Continued).

Reaction	Temperature or Energy	Cross Section or Reaction Rate	Reference
$NO^+ + NO_2^- \rightarrow$ Unspec.	300^oK	$1.75 \pm 0.6 \times 10^{-7}\ cm^3\ s^{-1}$	9
$NO^+ + NO_2^- \rightarrow$ Unspec.	300^oK	$2.1 \pm 0.6 \times 10^{-7}\ cm^3\ s^{-1}$	10
$NO^+ + NO_2^- \rightarrow$ Unspec.	0.1 to 200 eV	Graph B-1.A-12	7
$NO^+ + NO_3^- \rightarrow$ Unspec.	300^oK	$8.1 \pm 2.3 \times 10^{-7}\ cm^3\ s^{-1}$	1
$NO^+ + NO_3^- \rightarrow$ Unspec.	300^oK	$3.4 \pm 1.2 \times 10^{-8}\ cm^3\ s^{-1}$	9
$NO^+ + NO_3^- \rightarrow$ Unspec.	300^oK	$5.7 \pm 0.6 \times 10^{-8}\ cm^3\ s^{-1}$	8
$NO^+ + NO_3^- \rightarrow$ Unspec.	0.15 eV	$3.0 \times 10^{-7}\ cm^3\ s^{-1}$	1
$O_2^+ + O^- \rightarrow$ Unspec.	300^oK	$1.0 \pm 0.4 \times 10^{-7}\ cm^3\ s^{-1}$	1
$O_2^+ + O^- \rightarrow$ Unspec.	0.15 to 80 eV	Table B-1.A-13 Graph B-1.A-14	11
$O_2^+ + O_2^- \rightarrow$ Unspec.	300^oK	$1.0 \pm 0.1 \times 10^{-7}\ cm^3\ s^{-1}$	13
$O_2^+ + O_2^- \rightarrow$ Unspec.	300^oK	$4.2 \pm 1.3 \times 10^{-7}\ cm^3\ s^{-1}$	1
$O_2^+ + O_2^- \rightarrow$ Unspec.	0.15 to 14 eV	Table B-1.A-10 Graph B-1.A-11	7
$O_2^+ + NO_2^- \rightarrow$ Unspec.	300^oK	$4.1 \pm 1.3 \times 10^{-7}\ cm^3\ s^{-1}$	1
$O_2^+ + NO_2^- \rightarrow$ Unspec.	0.1 to 180 eV	Graph B-1.A-12	7
$O_2^+ + NO_3^- \rightarrow$ Unspec.	300^oK	$1.3 \pm 0.4 \times 10^{-7}\ cm^3\ s^{-1}$	1
$O_2^+ + NO_3^- \rightarrow$ Unspec.	0.15 to 700 eV	$1.2 \times 10^{-7}\ cm^3\ s^{-1}$ (invariant with energy)	1
$Ar_2^+ + F^- \rightarrow Ar\ F^* + Ar$	300^oK	$1.1 \times 10^{-6}\ cm^3\ s^{-1}$	14
$Kr_2^+ + F^- \rightarrow Kr\ F^* + Kr$	300^oK	$2 - 3 \times 10^{-6}\ cm^3\ s^{-1}$	15

Tabular Data B-1.A-1. (Concluded).

Reaction	Temperature or Energy	Cross Section or Reaction Rate	Reference
$I_2^+ + I^- \rightarrow$ Unspec	300^oK	1.22 to $1.47 \times 10^{-7}\ cm^3\ s^{-1}$	1
$Xe_2^+ + F^- \rightarrow XeF^* + Xe$	300^oK	$1.0 \times 10^{-6}\ cm^3\ s^{-1}$	4
$C\,C\ell_2^+$, $C\,C\ell_3^+ + C\ell^- \rightarrow$ Unspec.	300^oK	$4.5 \pm 0.5 \times 10^{-8}\ cm^3\ s^{-1}$	8
$C\,C\ell_2F^+$, $C\,C\ell F_2^+ + C\ell^- \rightarrow$ Unspec.	300^oK	$4.1 \pm 0.4 \times 10^{-8}\ cm^3\ s^{-1}$	8
$H_3O^+\cdot(H_2O)_3 + \left\{\begin{array}{l} NO_3^- \\ NO_2^- \\ NO_2^-\cdot H_2O \\ NO_3^-\cdot H_2O \end{array}\right. \rightarrow$ Unspec.	300^oK	$5.5 \pm 1.0 \times 10^{-8}\ cm^3\ s^{-1}$	16
$H_3O^+\cdot(H_2O)_3 + \left\{\begin{array}{l} NO_3^-\cdot HNO_3 \\ NO_3^-\cdot H_2O \\ NO_3^-\cdot(HNO_3)_2 \end{array}\right. \rightarrow$ Unspec.	300^oK	$5.7 \pm 1.0 \times 10^{-8}\ cm^3\ s^{-1}$	16

Tabular Data B-1.A-2. Three-body reactions.

Reaction	Temperature or Energy	Cross Section or Reaction Rate	Reference
$He^{+} + F^{-} + He \rightarrow HeF^{*} + He$	300°K	Table B-1.A-15 Graph B-1.A-16	17
$He_2^{+} + F^{-} + He \rightarrow He_2F^{*} + He$	300°K	Table B-1.A-17 Graph B-1.A-18	18
$O_4^{+} + O_2^{-} + O_2 \rightarrow [O_6] + O_2$	300°K	Graph B-1.A-19	19
$O_4^{+} + O_4^{-} + O_2 \rightarrow [O_8] + O_2$	300°K	Graph B-1.A-19	19
$Ne^{+} + F^{-} + Ne \rightarrow NeF^{*} + Ne$	300°K	Table B-1.A-15 Graph B-1.A-16	17
$Ne_2^{+} + F^{-} + Ne \rightarrow Ne_2F^{*} + Ne$	300°K	Table B-1.A-17 Graph B-1.A-18	18
$Ar^{+} + F^{-} + Ar \rightarrow ArF^{*} + Ar$	300°K	Table B-1.A-15 Graph B-1.A-16	17
$Ar^{+} + F^{-} + Ar \rightarrow ArF^{*} + Ar$	300°K	Table B-1.A-20 Graph B-1.A-21	20
$Ar^{+} + C\ell^{-} + Ar \rightarrow ArC\ell^{*} + Ar$	300°K	Table B-1.A-20 Graph B-1.A-21	20
$Ar^{+} + Br^{-} + Ar \rightarrow ArBr^{*} + Ar$	300°K	Table B-1.A-20 Graph B-1.A-21	20
$Ar^{+} + I^{-} + Ar \rightarrow ArI^{*} + Ar$	300°K	Table B-1.A-20 Graph B-1.A-21	20

Tabular Data B-1.A-2. (Continued).

Reaction	Temperature or Energy	Cross Section or Reaction Rate	Reference
$Ar_2^+ + F^- + Ar \rightarrow Ar_2F^* + Ar$	300°K	Table B-1.A-17 Graph B-1.A-18	18
$Kr^+ + F^- + M \rightarrow KrF^* + M$ (third body Unspecd.)	300°K	$2 - 3 \times 10^{-6}$ cm^3 s^{-1}	15
$Kr^+ + F^- + He \rightarrow KrF^* + He$	300°K	Table B-1.A-22 Graph B-1.A-23	21
$Kr^+ + F^- + Ne \rightarrow KrF^* + Ne$	300°K	Table B-1.A-22 Graph B-1.A-23	21
$Kr^+ + F^- + Ar \rightarrow KrF^* + Ar$	300°K	Table B-1.A-22 Graph B-1.A-23	21
$Kr^+ + F^- + Kr \rightarrow KrF^* + Kr$	300°K	Table B-1.A-15 Graph B-1.A-16	17
$Kr^+ + F^- + Xe \rightarrow KrF^* + Xe$	300°K	Table B-1.A-22 Graph B-1.A-23	21
$Kr_2^+ + F^- + He \rightarrow Kr_2F^* + He$	300°K	Table B-1.A-24 Graph B-1.A-25	21
$Kr_2^+ + F^- + Ne \rightarrow Kr_2F^* + Ne$	300°K	Table B-1.A-24 Graph B-1.A-25	21
$Kr_2^+ + F^- + Ar \rightarrow Kr_2F^* + Ar$	300°K	Table B-1.A-24 Graph B-1.A-25	21
$Kr_2^+ + F^- + Kr \rightarrow Kr_2F^* + Kr$	300°K	Table B-1.A-17 Graph B-1.A-18	18

Tabular Data B-1.A-2. (Concluded).

Reaction	Temperature or Energy	Cross Section or Reaction Rate	Reference
$Kr_2^+ + F^- + Xe \rightarrow Kr_2F^* + Xe$	300^oK	Table B-1.A-24 Graph B-1 A-25	21
$Xe^+ + F^- + Xe \rightarrow XeF^* + F$	300^oK	Table B-1.A-15 Graph B-1.A-16	17
$Xe_2^+ + F^- + Xe \rightarrow Xe_2F^* + Xe$	300^oK	Table B-1.A-17 Graph B-1.A-18	18
$Hg^+ + F^- + Ar \rightarrow HgF^* + Ar$	300^oK	Table B-1.A-26 Graph B-1.A-27	20
$Hg^+ + C\ell^- + Ar \rightarrow HgC\ell + Ar$	300^oK	Table B-1.A-26 Graph B-1.A-27	20
$Hg^+ + Br^- + Ar \rightarrow HgBr^* + Ar$	300^oK	Table B-1.A-26 Graph B-1.A-27	20
$Hg^+ + I^- + Ar \rightarrow HgI^* + Ar$	300^oK	Table B-1.A-26 Graph B-1.A-27	20

Tabular Data B-1.A-3. Cross section for the two-body mutual neutralization of H^+ and H^- ions.

Barycentric Energy (eV)	Recombination Cross Section (cm^2)
	$H^+ + H^- \rightarrow H + H$
1.0 E-01	2.84 E-13
2.0 E-01	1.71 E-13
3.0 E-01	1.25 E-13
5.0 E-01	8.61 E-14
1.0 E 00	5.18 E-14
2.0 E 00	3.45 E-14
3.0 E 00	2.70 E-14
5.0 E 00	2.00 E-14
1.0 E 01	1.43 E-14
2.0 E 01	1.36 E-14
3.0 E 01	1.50 E-14
5.0 E 01	1.77 E-14
1.0 E 02	2.32 E-14
2.0 E 02	1.97 E-14
3.0 E 02	1.50 E-14
5.0 E 02	1.27 E-14
7.0 E 02	1.36 E-14
1.0 E 03	1.24 E-14
2.0 E 03	7.26 E-15
3.0 E 03	5.40 E-15
5.0 E 03	3.38 E-15

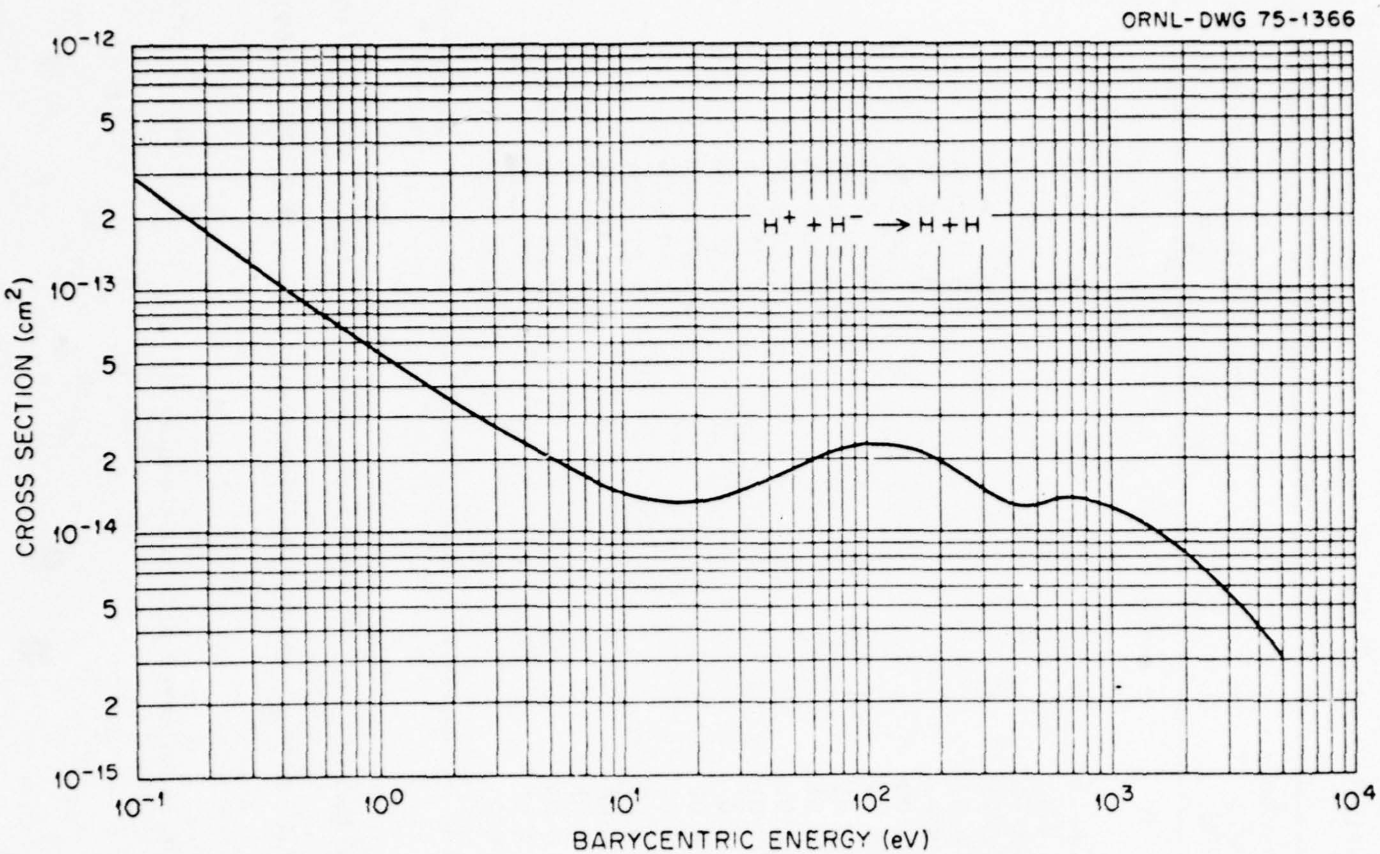
References:

J. Moseley, W. Aberth, and J.R. Peterson, Phys. Rev. Letts. 24, 435 (1970).

R.D. Rundel, R.L. Aitken, and M.F.A. Harrison, J. Phys. B 2, 954 (1969).

Accuracy:

The total error is believed not to exceed ± 35%.



Graphical Data B-1.A-4. Cross sections for the two-body mutual neutralization of H^+ and H^- ions. (Tabular data were presented on the previous page.)

Tabular Data B-1.A-5. Cross sections for the two-body mutual neutralization of He^+ with H^- ions and of He^+ with D^- ions.

Barycentric Energy (eV)	Recombination Cross Section (cm^2)	
	$He^+ + D^-$	$He^+ + H^-$
1.0 E 00	1.00 E-13	
2.0 E 00	7.36 E-14	
3.0 E 00	6.14 E-14	
5.0 E 00	5.09 E-14	
1.0 E 01	3.88 E-14	
2.0 E 01	2.98 E-14	
3.0 E 01	2.59 E-14	
5.0 E 01	2.18 E-14	
1.0 E 02	1.78 E-14	
2.0 E 02	1.53 E-14	
3.0 E 02	1.42 E-14	1.44 E-14
5.0 E 02	1.25 E-14	1.23 E-14
9.0 E 02		1.09 E-14
1.5 E 03		9.06 E-15
2.0 E 03		9.27 E-15
4.0 E 03		4.42 E-15
6.0 E 03		1.93 E-15

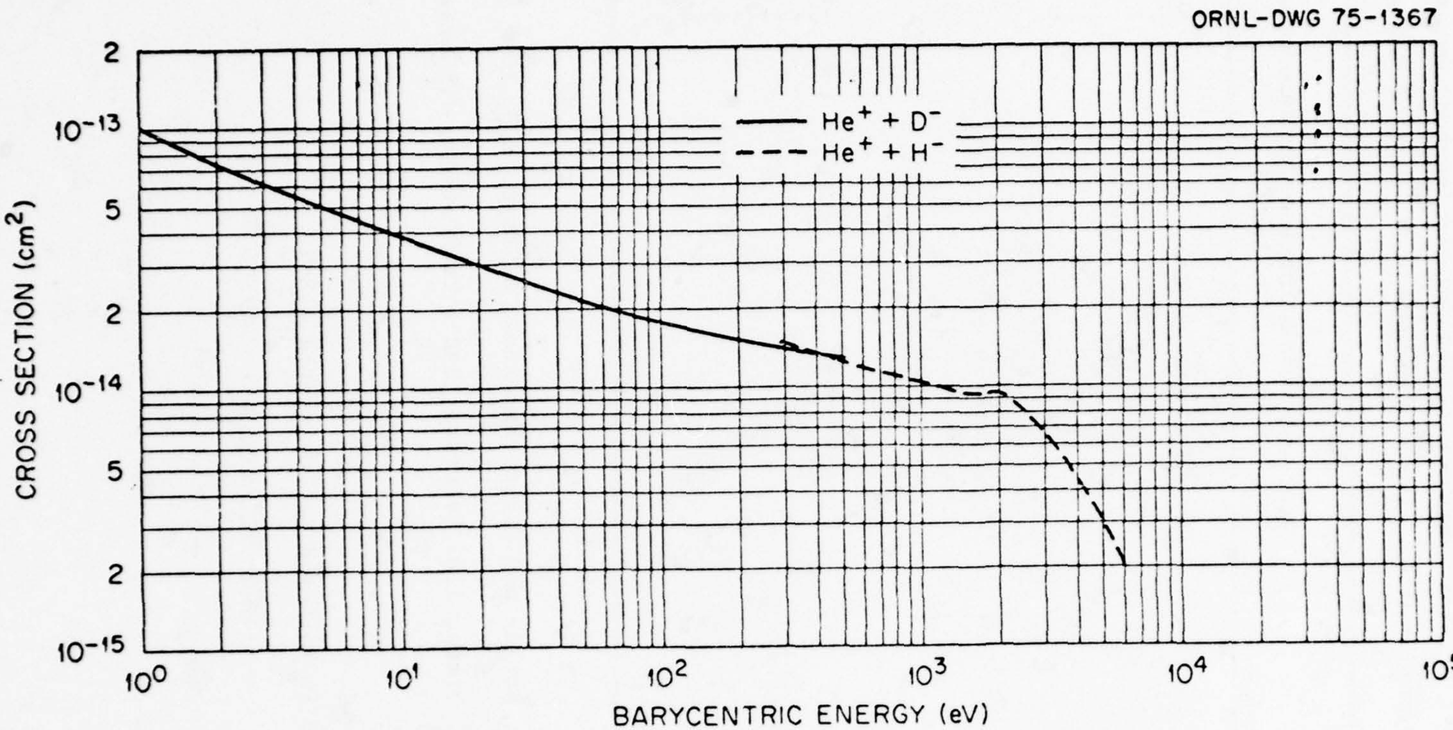
References:

$He^+ + H^-$: T.D. Gailey and M.F.A. Harrison, J. Phys. B 3, 1098 (1970).

$He^+ + D^-$: R.E. Olson, J.R. Peterson, and J.T. Moseley, J. Chem. Phys. 53, 3391 (1970).

Accuracy:

The total error is believed not to exceed ± 35%.



Graphical Data B-1.A-6. Cross sections for mutual neutralization of He^+ with D^- and H^-. (Tabular data were presented on the previous page.)

Tabular Data B-1.A-7. Cross sections for the two-body mutual neutralization of N^+ with O^- ions, of O^+ with O^- ions, and of H_2^+ with D^- ions.

Barycentric Energy (eV)	Recombination Cross Section (cm^2)		
	$N^+ + O^-$	$O^+ + O^-$	$H_2^+ + D^-$
1.0 E-01		9.38 E-13	7.21 E-13
1.2 E-01	8.45 E-13	8.00 E-13	6.00 E-13
2.0 E-01	5.50 E-13	4.92 E-13	3.72 E-13
3.0 E-01	4.00 E-13	3.51 E-13	2.67 E-13
5.0 E-01	2.74 E-13	2.32 E-13	1.86 E-13
1.0 E 00	1.83 E-13	1.42 E-13	1.16 E-13
2.0 E 00	1.21 E-13	1.00 E-13	7.41 E-14
3.0 E 00	9.73 E-14	8.36 E-14	5.75 E-14
5.0 E 00	7.41 E-14	7.02 E-14	4.51 E-14
5.6 E 00	7.23 E-14	6.68 E-14	4.21 E-14
1.0 E 01	5.62 E-14	5.88 E-14	4.39 E-14
1.5 E 01	4.81 E-14	5.46 E-14	3.60 E-14
2.0 E 01		5.25 E-14	2.77 E-14
3.0 E 01			3.10 E-14
4.0 E 01			2.94 E-14
5.0 E 01			2.66 E-14
6.0 E 01			2.53 E-14

References:

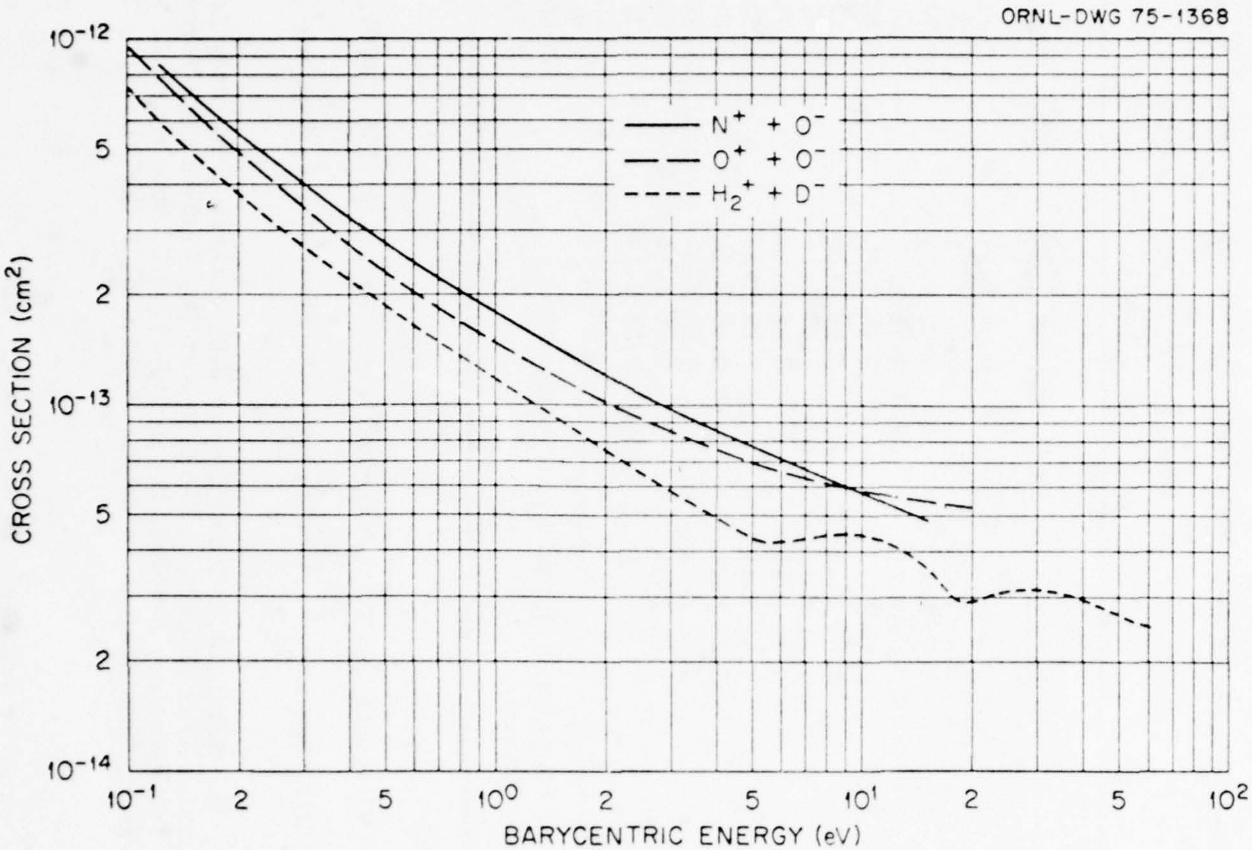
$N^+ + O^-$: W. Aberth and J.R. Peterson, Phys. Rev. A 1, 158 (1970).

$O^+ + O^-$: J.T. Moseley, W. Aberth, and J.R. Peterson, J. Geophys. Res. 77, 255 (1972).

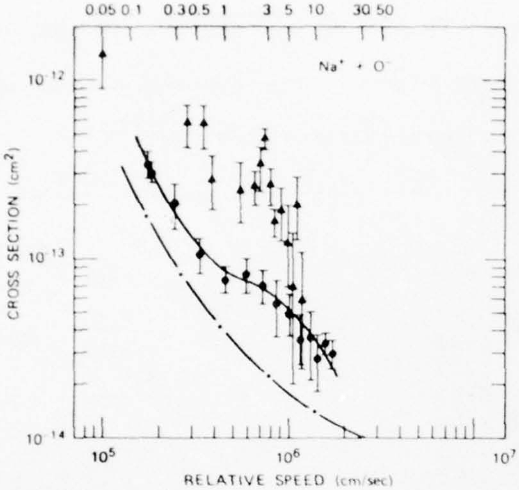
$H_2^+ + D^-$: W. Aberth, J.T. Moseley, and J.R. Peterson, Two Body Ion-Ion Neutralization Cross Sections, AFCRL Report No. 71-0481, Air Force Cambridge Research Laboratories, Bedford, Mass. (1971); J.T. Moseley, R.E. Olson, and J.R. Peterson, Case Studies in Atomic Physics 5, 1 (1975).

Accuracy:

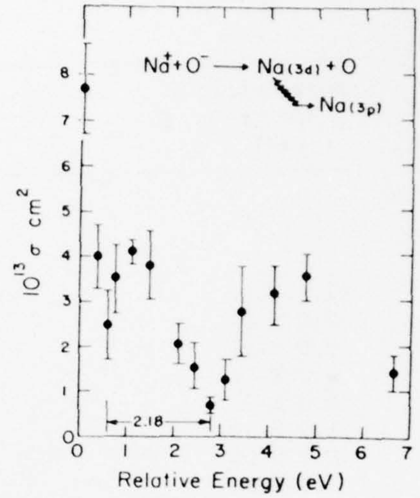
The total error is believed not to exceed ± 35%



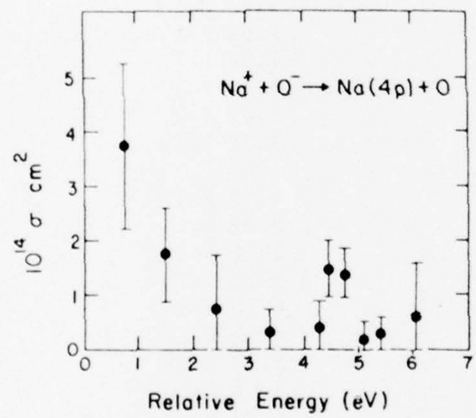
Graphical Data B-1.A-8. Cross sections for mutual neutralization reactions. (Tabular data were presented on the previous page.)



(a)



(b)



(c)

(a) Circles are a total cross section, triangles are for light emission in the 3p → 2s transition of Na.

(b) Light emission in the 3d → 3p transition of Na.

(c) Light emission in the 4p → 3s transition of Na.

From J. T. Moseley et al., J. Geophys. Res. 77, 255 (1972) and J. Weiner et al., Phys. Rev. A 4, 1825 (1971).

Graphical Data B-1.A-9. Cross sections for mutual neutralization of Na^+ by O^-.

Tabular Data B-1.A-10. Cross sections for the two-body mutual neutralization of O_2^+ with O_2^- ions and of N_2^+ with O_2^- ions.

Barycentric Energy (eV)	Recombination Cross Section (cm^2)	
	$N_2^+ + O_2^-$	$O_2^+ + O_2^-$
1.5 E-01	1.20 E-12	2.42 E-12
2.0 E-01	1.00 E-12	1.91 E-12
3.0 E-01	7.20 E-13	1.48 E-12
4.0 E-01	6.12 E-13	1.25 E-12
6.0 E-01	4.88 E-13	1.03 E-12
1.0 E 00	3.57 E-13	7.48 E-13
2.0 E 00	2.21 E-13	3.87 E-13
3.0 E 00	1.64 E-13	2.29 E-13
4.0 E 00	1.27 E-13	1.73 E-13
4.5 E 00	1.13 E-13	1.80 E-13
5.0 E 00	1.20 E-13	1.95 E-13
6.0 E 00	1.42 E-13	1.55 E-13
7.0 E 00	1.59 E-13	1.35 E-13
8.0 E 00	1.52 E-13	1.29 E-13
9.0 E 00	1.42 E-13	1.07 E-13
1.0 E 01	1.27 E-13	1.00 E-13
1.2 E 01	9.12 E-14	1.09 E-13
1.4 E 01		9.00 E-14
1.5 E 01	1.18 E-13	
2.0 E 01	6.73 E-14	
2.5 E 01	7.30 E-14	
2.8 E 01	5.53 E-14	
3.2 E 01	6.22 E-14	
4.4 E 01	4.98 E-14	
5.0 E 01	5.98 E-14	
7.0 E 01	3.66 E-14	
8.0 E 01	4.33 E-14	
9.0 E 01	4.10 E-14	

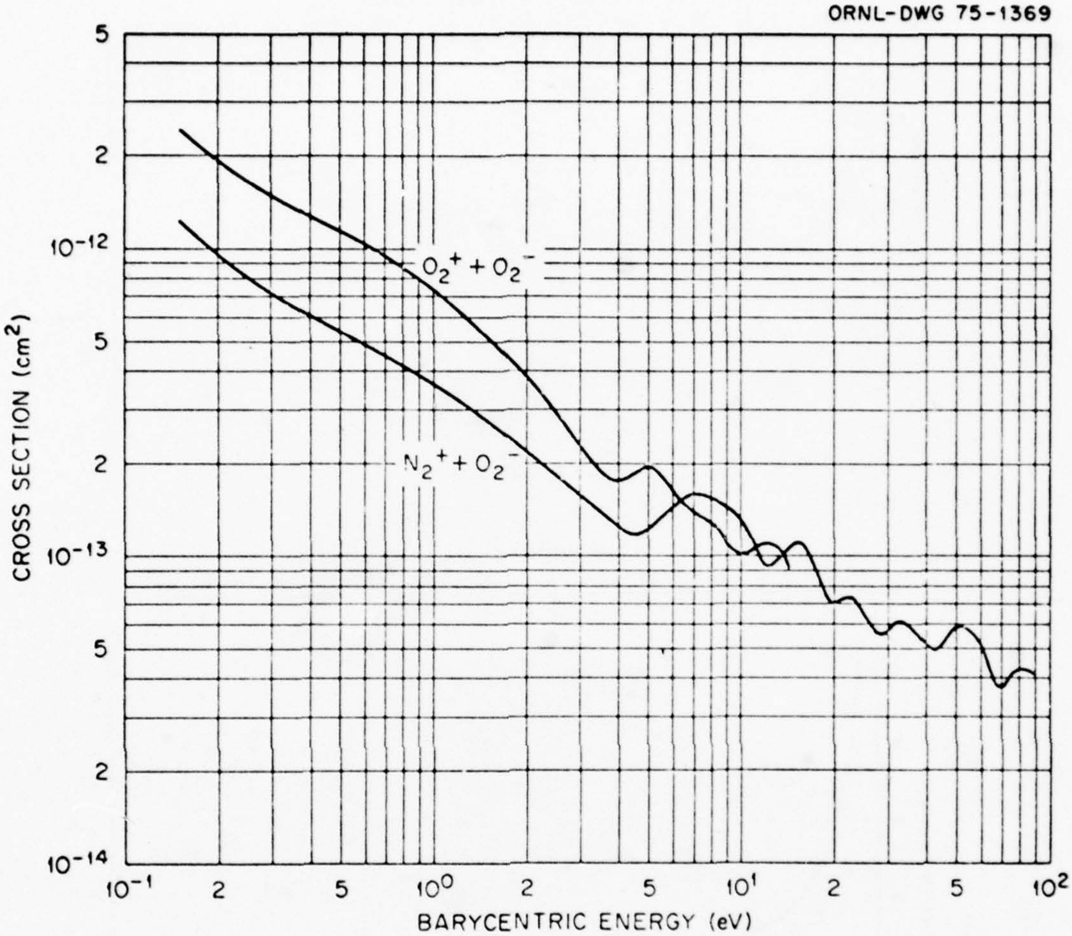
References:

$O_2^+ + O_2^-$: J.R. Peterson, W. Aberth, J.T. Moseley, and J.R. Sheridan, Phys. Rev. A 3, 1651 (1971).

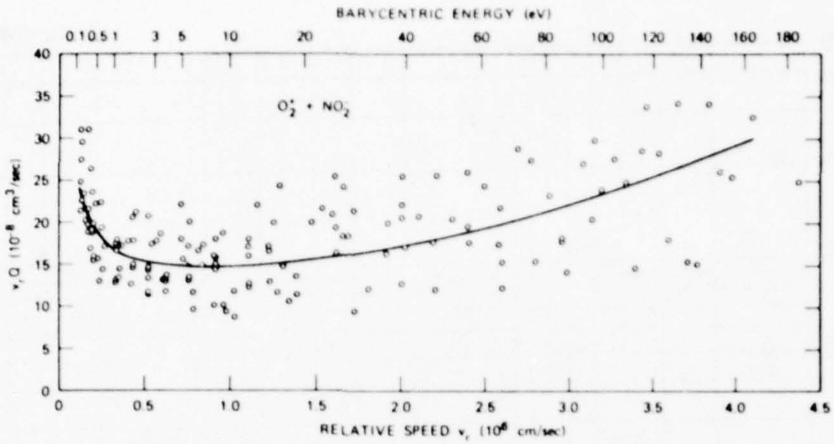
$N_2^+ + O_2^-$: W. Aberth and J.R. Peterson, Phys. Rev. A 1, 158 (1970).

Accuracy:

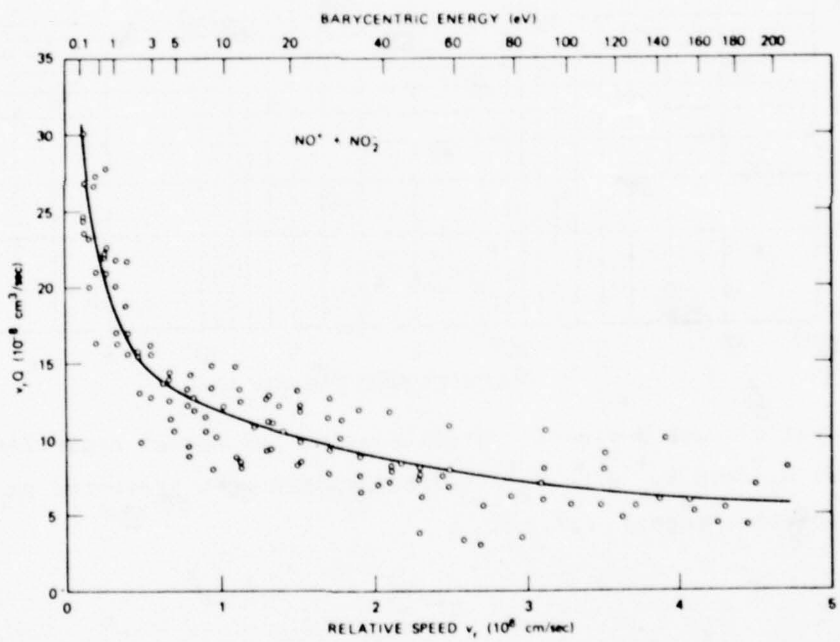
The total error is believed not to exceed ± 35%.



Graphical Data B-1.A-11. Cross section for mutual neutralization of O_2^+ and N_2^+ with O_2^-. (Tabular data were presented on the previous page.)



(a)



(b)

Graphical Data B-1.A-12. Experimental data on mutual neutralization of O_2^+ and NO^+ with NO_2^-. Data are in the form of cross sections multiplied by relative speed of the interacting ions to simulate the behavior of the reaction rate. [From J. R. Peterson et al., Phys. Rev. A 3, 1651 (1971)].

Tabular Data B-1.A-13. Cross sections for the two-body mutual neutralization of O_2^+ with O^- ions and of NO^+ with O^- ions.

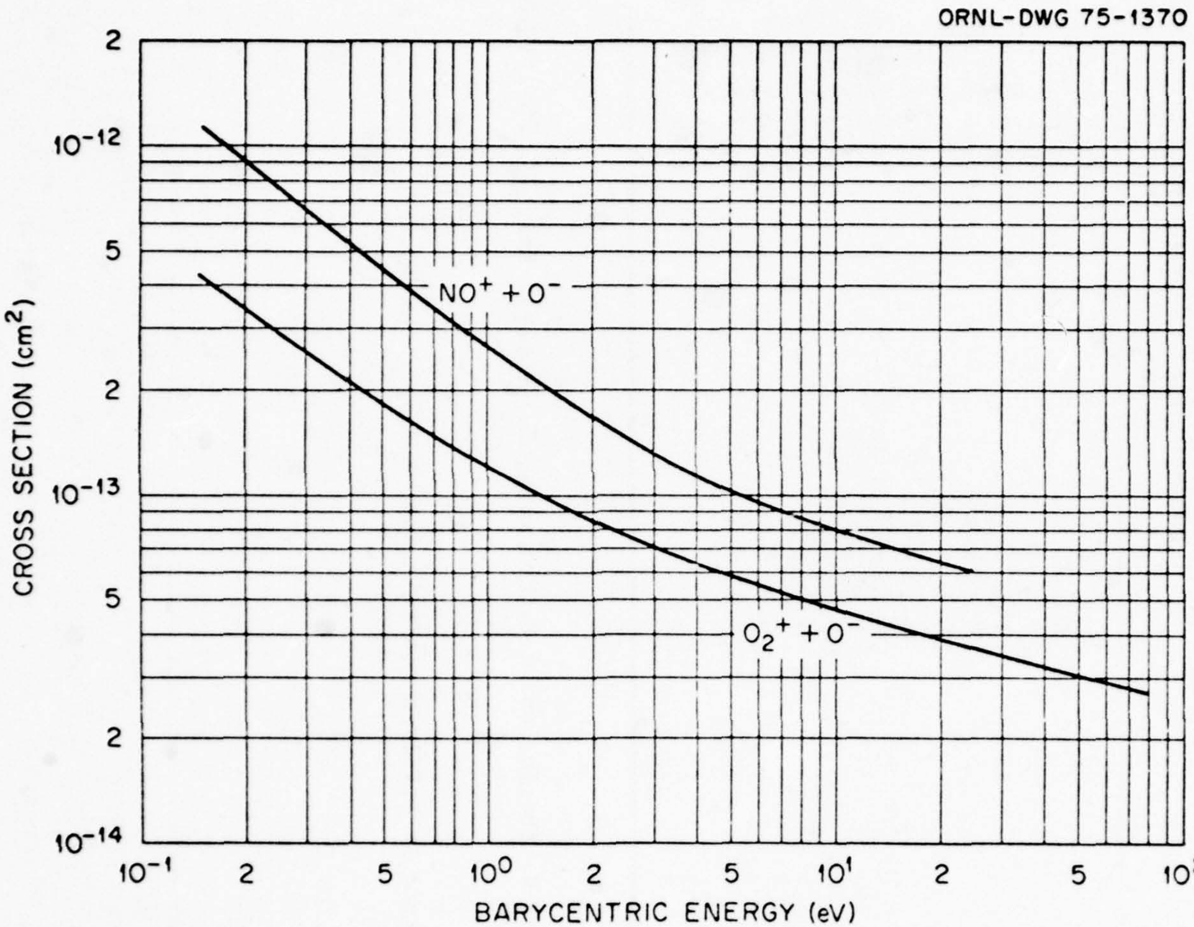
Barycentric Energy (eV)	Recombination Cross Section (cm^2) $NO^+ + O^-$	$O_2^+ + O^-$
1.5 E-01	1.12 E-12	4.17 E-13
2.0 E-01	8.97 E-13	3.44 E-13
3.0 E-01	6.41 E-13	2.53 E-13
5.0 E-01	4.44 E-13	1.83 E-13
1.0 E 00	2.71 E-13	1.19 E-13
2.0 E 00	1.66 E-13	8.53 E-14
5.0 E 00	1.00 E-13	5.88 E-14
1.0 E 01	7.94 E-14	4.74 E-14
2.0 E 01	6.30 E-14	3.80 E-14
2.5 E 01	5.93 E-14	3.37 E-14
5.0 E 01		3.11 E-14
8.0 E 01		2.67 E-14

Reference:

J.T. Moseley, W. Aberth, and J.R. Peterson, J. Geophys. Res. 77, 255 (1972).

Accuracy:

The total error is believed not to exceed ± 35%.



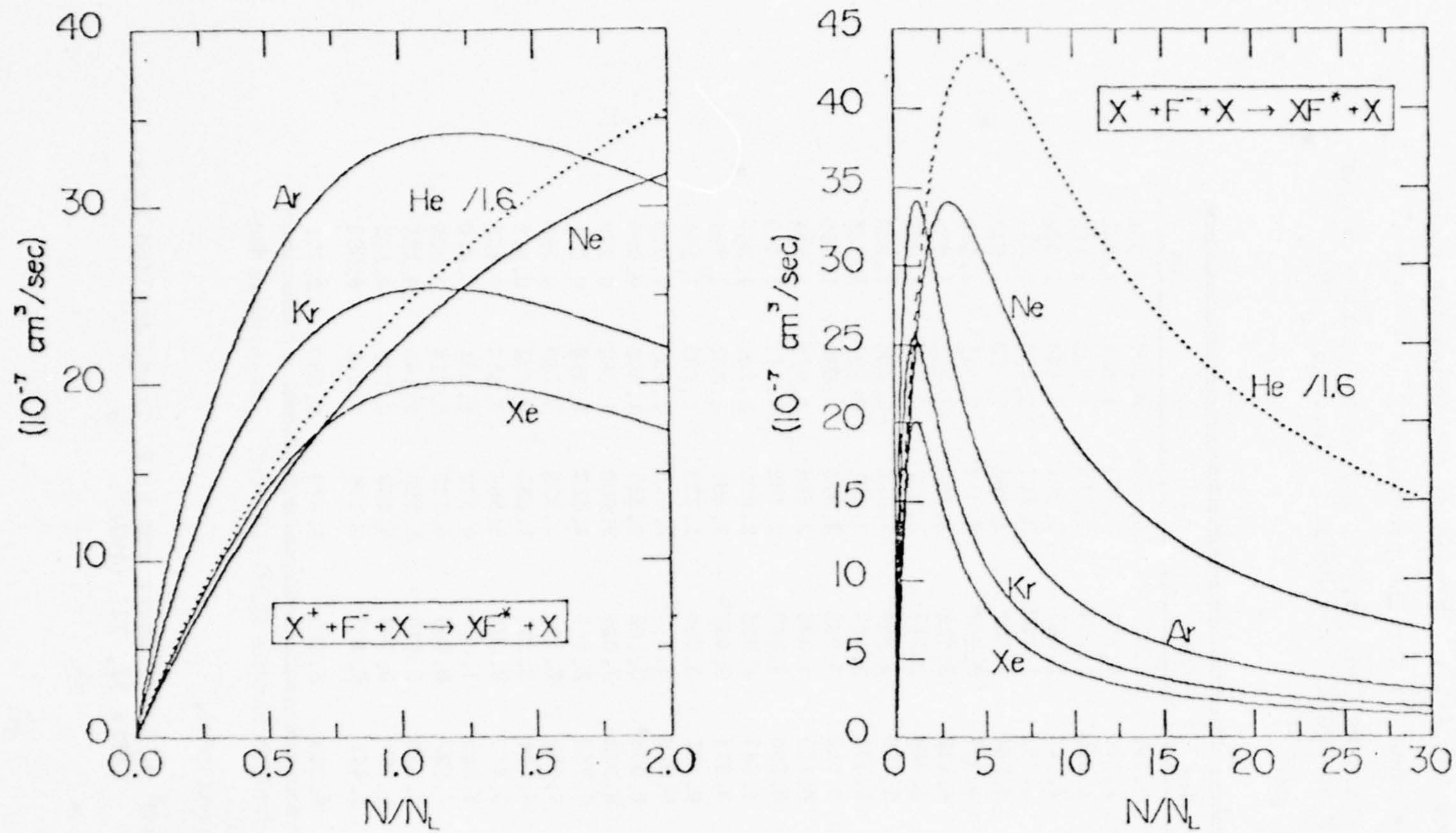
Graphical Data B-1.A-14. Cross sections for the mutual neutralization of NO^+ and O_2^+ with O^-. (Tabular data were presented on the previous page.)

Tabular Data B-1.A-15. Three-body recombination rates $\alpha(10^{-6}\ cm^3\ sec^{-1})$ for the processes $X^+ + F^- + X \rightarrow XF^* + X$, ($X \equiv$ He, Ne, Ar, Kr, Xe) as a function of gas density N at 300°K. Low-density limit is $\alpha_0\ N/N_L$ $(10^{-6}\ cm^3\ sec^{-1})$.

N/N_L [a]	He	Ne	Ar	Kr	Xe
0.1	0.591	0.315	0.817	0.597	0.351
0.2	1.110	0.601	1.434	1.061	0.662
0.4	1.990	1.107	2.312	1.739	1.193
0.6	2.717	1.541	2.867	2.173	1.592
0.8	3.333	1.913	3.197	2.420	1.849
1.0	3.864	2.232	3.364	2.528	1.978
1.2	4.327	2.502	3.417 [b]	2.541 [b]	2.010 [b]
1.4	4.732	2.728	3.393	2.492	1.978
1.6	5.088	2.914	3.321	2.409	1.909
1.8	5.400	3.064	3.219	2.306	1.820
2.0	5.674	3.180	3.101	2.197	1.725
2.2	5.912	3.269	2.976	2.086	1.629
2.4	6.118	3.332	2.850	1.979	1.536
2.6	6.296	3.373	2.725	1.877	1.449
2.8	6.447	3.395	2.605	1.781	1.369
3.0	6.574	3.402 [b]	2.491	1.692	1.294
3.5	6.801	3.366	2.233	1.495	1.134
4.0	6.920	3.277	2.013	1.334	1.005
4.5	6.958 [b]	3.160	1.827	1.200	0.900
5	6.933	3.028	1.669	1.089	0.813
6	6.756	2.755	1.417	0.916	0.681
7	6.485	2.499	1.228	0.789	0.585
8	6.174	2.270	1.082	0.692	0.512
9	5.853	2.071	0.966	0.616	0.455
10	5.541	1.899	0.872	0.554	0.410
20	3.392	0.998	0.439	0.277	0.205
30	2.368	0.670	0.293	0.185	0.137
40	1.797	0.503	0.220	0.139	0.102
50	1.441	0.403	0.176	0.111	0.082
α_0	6.340	3.305	9.579	6.936	3.777

[a] N_L is Loschmidt's number ($2.69 \times 10^{19}\ cm^{-3}$), the number density at STP.
[b] Indicates peak value.

References: M. R. Flannery and T. P. Yang, Applied Phys. Letts 32, 327 (1978).



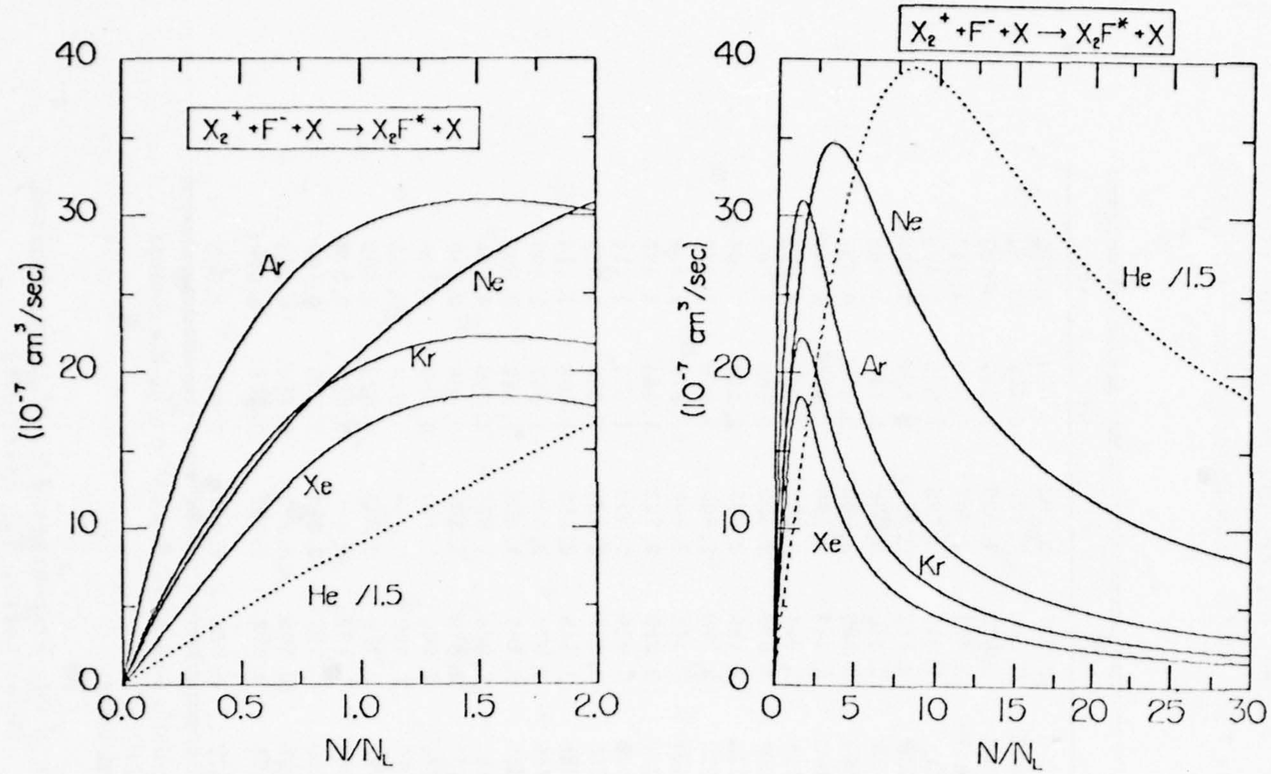
Graphical Data B-1.A-16. Ionic recombination coefficients $\alpha(cm^3\ sec^{-1})$ for the processes $X^+ + F^- + X \rightarrow XF^* + X$ ($X \equiv$ He, Ne, Ar, Kr, Xe) as a function of neutral-gas density N (in units of Loschmidt's number N_L, $2.69 \times 10^{19}\ cm^{-3}$). Gas X is as indicated on each curve. Note that the rates for the He case have been divided by 1.6. (Tabular data were presented on the previous page.)

Tabular Data B-1.A-17. Three-body recombination rates $\alpha(10^{-6}\ cm^3\ sec^{-1})$ for the processes $X_2^+ + F^- + X \rightarrow [X_2F]^* + X$ ($X \equiv$ He, Ne, Ar, Kr, Xe) as a function of gas density N at 300°K. Low-density limit is $\alpha_0\ N/N_L$ $(10^{-6}\ cm^3\ sec^{-1})$.

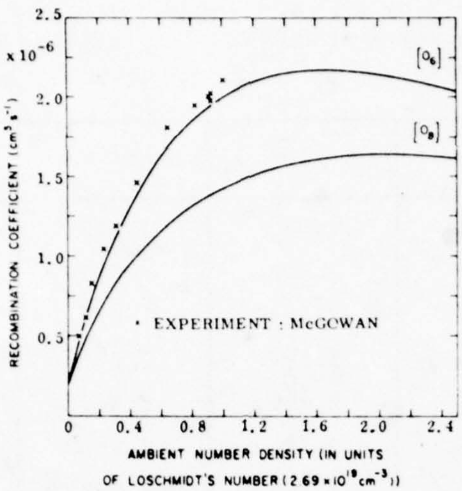
N/N_L[a]	He	Ne	Ar	Kr	Xe
0.1	0.154	0.315	0.683	0.350	0.192
0.2	0.302	0.593	1.195	0.649	0.384
0.4	0.583	1.070	1.925	1.147	0.762
0.6	0.851	1.471	2.407	1.535	1.114
0.8	1.107	1.815	2.725	1.825	1.409
1.0	1.356	2.113	2.924	2.024	1.627
1.2	1.597	2.370	3.038	2.147	1.765
1.4	1.833	2.593	3.089	2.209	1.832
1.6	2.063	2.783	3.096[b]	2.224[b]	1.845[b]
1.8	2.288	2.944	3.071	2.207	1.819
2.0	2.508	3.079	3.023	2.166	1.768
2.2	2.723	3.190	2.960	2.110	1.704
2.4	2.933	3.278	2.886	2.046	1.632
2.6	3.137	3.348	2.806	1.976	1.558
2.8	3.336	3.399	2.722	1.904	1.485
3.0	3.528	3.436	2.636	1.832	1.414
3.5	3.980	3.471[b]	2.421	1.659	1.252
4.0	4.388	3.445	2.216	1.502	1.114
4.5	4.746	3.379	2.028	1.363	1.000
5	5.055	3.287	1.859	1.242	0.902
6	5.519	3.064	1.576	1.046	0.754
7	5.795	2.829	1.358	0.898	0.646
8	5.914[b]	2.604	1.188	0.786	0.565
9	5.912	2.398	1.054	0.698	0.502
10	5.823	2.214	0.946	0.628	0.452
20	3.950	1.189	0.468	0.313	0.226
30	2.750	0.797	0.312	0.209	0.150
40	2.082	0.598	0.234	0.156	0.113
50	1.671	0.479	0.187	0.125	0.090
α_0	1.572	3.373	8.061	3.841	1.949

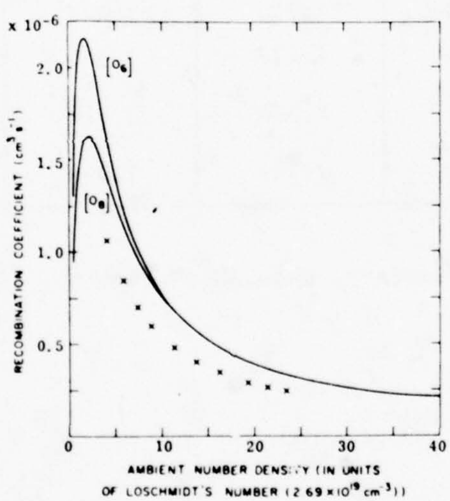
[a] N_L is Loschmidt's number ($2.69 \times 10^{19}\ cm^{-3}$), the number density at STP.
[b] Indicates peak value.

Reference: M. R. Flannery and T. P. Yang, Applied Phys. Letts. 32, 356 (1978).



Graphical Data B-1.A-18. Ionic recombination coefficients $\alpha(\mathrm{cm}^3\ \mathrm{sec}^{-1})$ for the processes $X_2^+ + F^- + X \rightarrow [X_2F]^* + X$ ($X \equiv$ He, Ne, Ar, Kr, Xe) as a function of neutral-gas density N (in units of Loschmidt's number N_L, $2.69 \times 10^{19}\ \mathrm{cm}^{-3}$). The square brackets indicate that the molecule $[X_2F]^*$ may not remain bound. Gas X is as indicated on each curve. Note that the rates for the He case have been divided by 1.5. (Tabular data were presented on the previous page.)



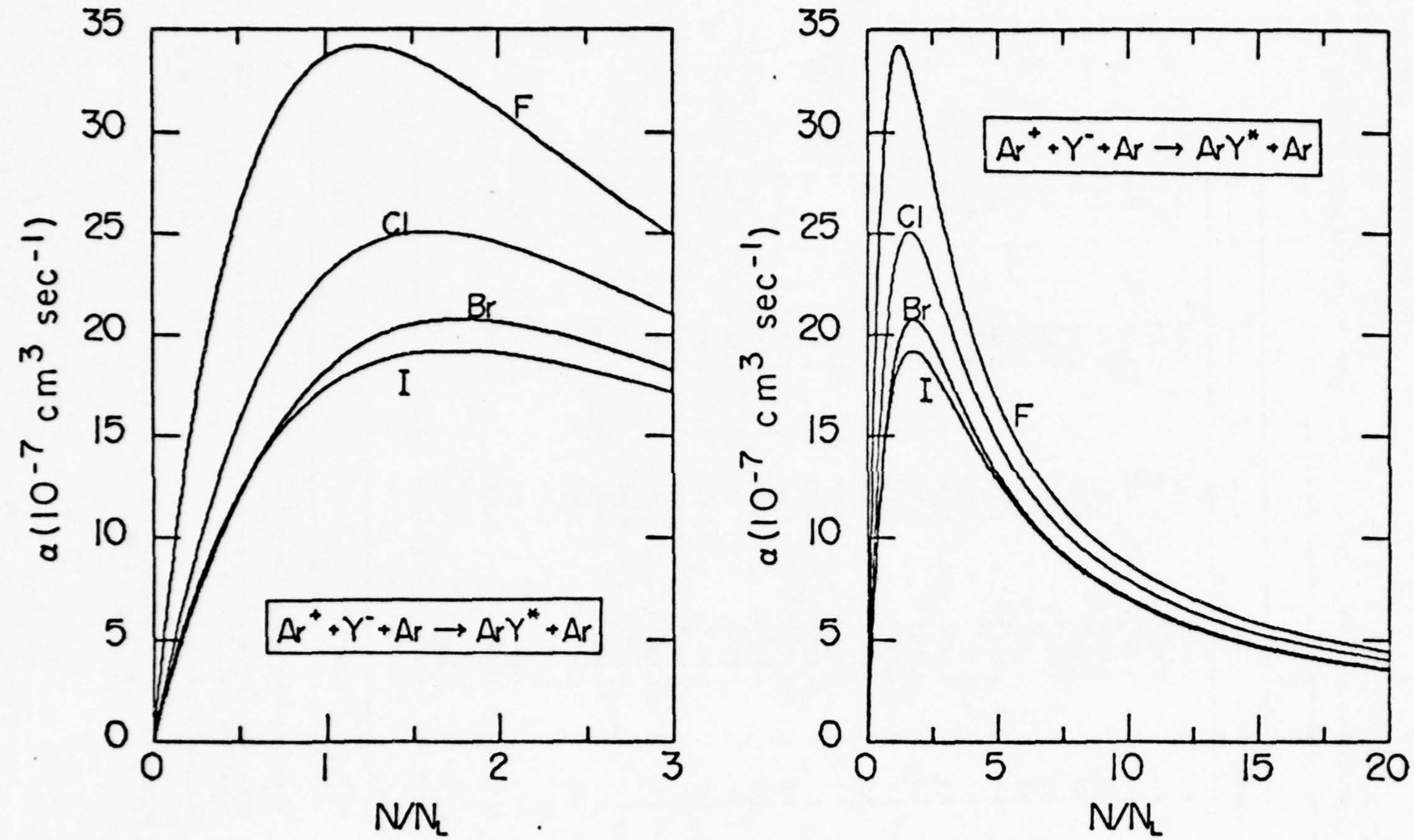


Graphical Data B-1.A-19. Rate coefficient $\alpha(cm^3\ sec^{-1})$ at 298°K for recombination in the systems $O_4^+ + O_2^- + O_2 \rightarrow [O_6] + O_2$ and $O_4^+ + O_4^- + O_2 \rightarrow [O_8] + O_2$ shown as a function of the O_2 number density. Lines are theoretical calculations (by Flannery), crosses at low densities are experimental data for recombination in an experiment where the nature of the ions was not specified (by McGowan), and the crosses at high densities are data for recombination of unknown ions in air (by Machler). Reproduced from the work of Bates and Flannery, J. Phys., B 2, 184 (1969).

Tabular Data B-1.A-20. Three-body recombination rates $\alpha(10^{-6}\ cm^3\ sec^{-1})$ for the process $Ar^+ + Y^- + Ar \rightarrow ArY^* + Ar$, with $Y^- \equiv F^-, C\ell^-, Br^-, I^-$, for various gas densities N at 300°K. Low and high density limits are $\alpha_0\ (N/N_L)$ and $\alpha_\infty(N_L/N)$.

N/N_L	F^-	Cl^-	Br^-	I^-
0.5	2.622	1.583	1.212	1.231
1.0	3.364	2.300	1.821	1.743
1.4	3.394	2.491	2.029	1.896
1.8	3.219	2.490	2.077	1.923
2.0	3.101	2.449	2.063	1.908
2.4	2.850	2.324	1.990	1.847
3.0	2.491	2.100	1.829	1.716
3.5	2.233	1.917	1.686	1.598
4.0	2.013	1.750	1.549	1.484
5.0	1.669	1.473	1.315	1.278
α_0	9.579	4.588	3.514	3.992
α_∞	8.783	7.949	7.098	6.863

Reference: M. R. Flannery, Chem. Phys. Letts., 56, 143 (1978).



Graphical Data B-1.A-21. Three-body ion-ion recombination coefficients $\alpha(cm^3\ sec^{-1})$ for the processes $Ar^+ + Y^- + Ar \rightarrow ArY^* + Ar$ ($Y^- \equiv F^-$, $C\ell^-$, Br^-, I^-) as a function of neutral-gas density N (in units of Loschmidt's number N_L, $2.69 \times 10^{19}\ cm^{-3}$). Negative ion denoted on each curve. (Tabular data were presented on the previous page.)

Tabular Data B-1.A-22. Three-body recombination rates $\alpha(10^{-6}\ \mathrm{cm}^3\ \mathrm{sec}^{-1})$ for the processes $Kr^+ + F^- + Rg \rightarrow KrF^* + Rg$ ($Rg \equiv$ He, Ne, Ar, Xe) for various gas densities N at 300°K. Low- and high-density limits are $\alpha_0\ (N/N_L)$ and $\alpha_\infty\ (N_L/N)$, respectively.

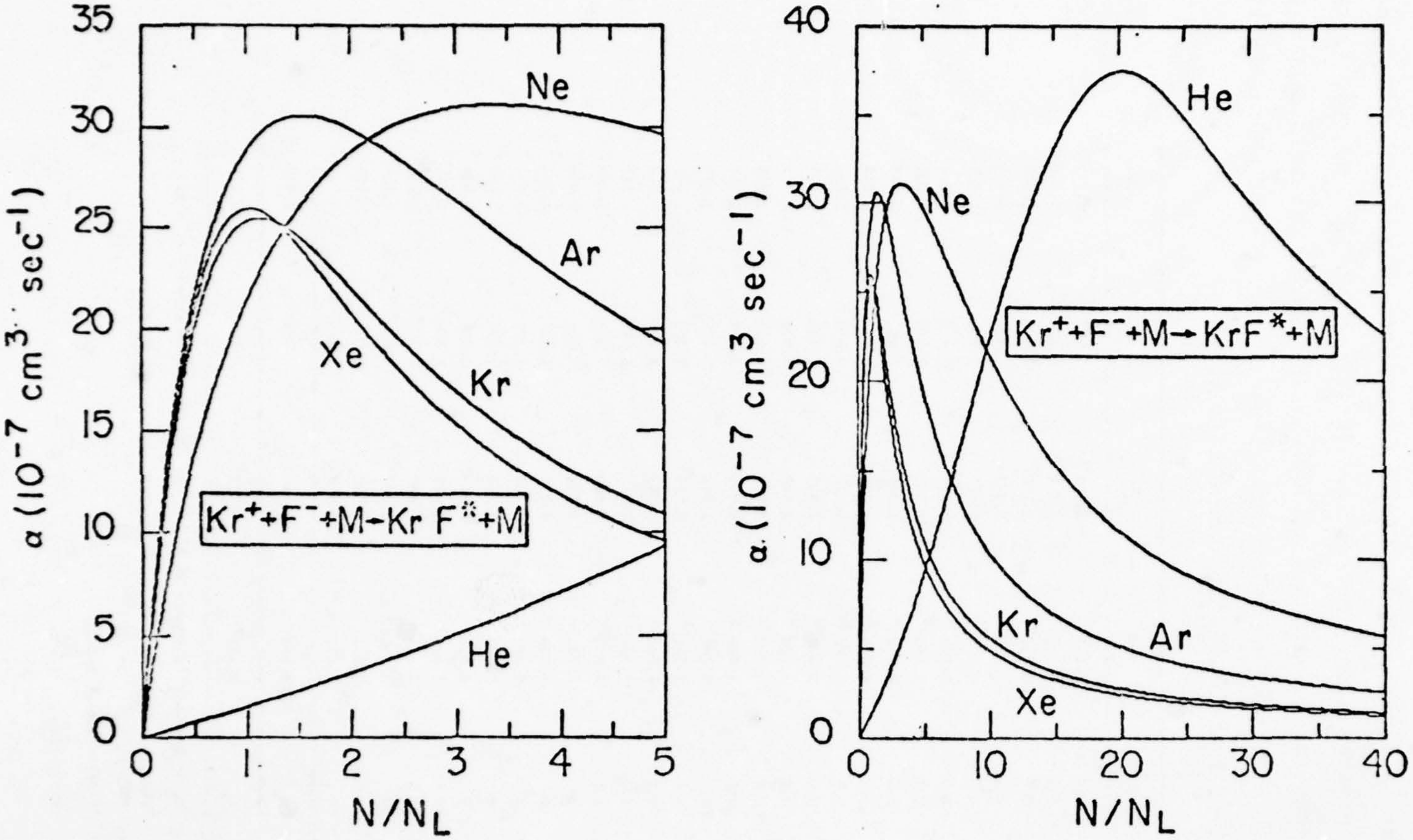
N/N_L[a]	He	Ne	Ar	Xe
0.1	1.400^{-2}[b]	3.618^{-1}	6.695^{-1}	5.896^{-1}
0.2	2.816^{-2}	6.678^{-1}	1.171	1.071
0.4	5.701^{-2}	1.165	1.886	1.806
0.6	8.657^{-2}	1.556	2.361	2.275
0.8	1.169^{-1}	1.873	2.676	2.517
1.0	1.479^{-1}	2.132	2.876	2.591[c]
1.2	1.797^{-1}	2.346	2.992	2.557
1.4	2.123^{-1}	2.522	3.046	2.462
1.6	2.457^{-1}	2.667	3.056[c]	2.338
1.8	2.799^{-1}	2.784	3.035	2.205
2.0	3.149^{-1}	2.877	2.991	2.072
2.2	3.508^{-1}	2.951	2.932	1.945
2.4	3.874^{-1}	3.008	2.864	1.827
2.6	4.248^{-1}	3.050	2.789	1.718
2.8	4.630^{-1}	3.079	2.711	1.618
3.0	5.021^{-1}	3.098	2.632	1.527
3.5	6.031^{-1}	3.108[c]	2.436	1.334
4.0	7.090^{-1}	3.079	2.250	1.181
4.5	8.194^{-1}	3.027	2.080	1.057
5	9.340^{-1}	2.959	1.925	9.551^{-1}
6	1.174	2.800	1.661	7.995^{-1}
7	1.427	2.632	1.449	6.866^{-1}
8	1.686	2.463	1.278	6.013^{-1}
9	1.947	2.300	1.140	5.346^{-1}
10	2.206	2.145	1.027	4.812^{-1}
20	3.746[c]	1.143	5.107^{-1}	2.406^{-1}
30	3.000	7.582^{-1}	3.400^{-1}	1.604^{-1}
40	2.255	5.676^{-1}	2.549^{-1}	1.203^{-1}
50	1.802	4.537^{-1}	2.039^{-1}	9.623^{-2}
α_0	1.391^{-1}	3.967	7.909	6.68[illegible]
α_∞	9.004^{1}	2.268^{1}	1.019^{1}	4.811

[a] N_L is Loschmidt's number ($2.69\ 10^{19}\ \mathrm{cm}^{-3}$), the number density at STP.

[b] The exponent denotes the power of ten by which the entry is to be multiplied.

[c] Indicates peak value.

Reference: M. R. Flannery and T. P. Yang, Appl. Phys. Letts. 33, 574 (1978).



Graphical Data B-1.A-23. Ionic recombination coefficients $\alpha(cm^3\ sec^{-1})$ at 300°K for $Kr^+ + F^- + M \rightarrow KrF^* + M$ ($M \equiv$ He, Ne, Ar, Kr, Xe) as a function of neutral-gas density N (in units of Loschmidt's number N_L, $2.69 \times 10^{19}\ cm^{-3}$). Buffer gas M is as indicated on each curve. (Tabular data were presented on the previous page.)

Tabular Data B-1.A-24. Three-body recombination rates $\alpha(10^{-6}\ cm^3\ sec^{-1})$, for the processes $Kr_2^+ + F^- + Rg \rightarrow [Kr_2F]^* + Rg$ (Rg $\equiv$ He, Ne, Ar, Xe), for various gas densities N at 300°K. The square brackets denote that the molecule Kr_2F^* may not remain bound. Low- and high-density limits are $\alpha_0\ (N/N_L)$ and $\alpha_\infty(N_L/N)$, respectively.

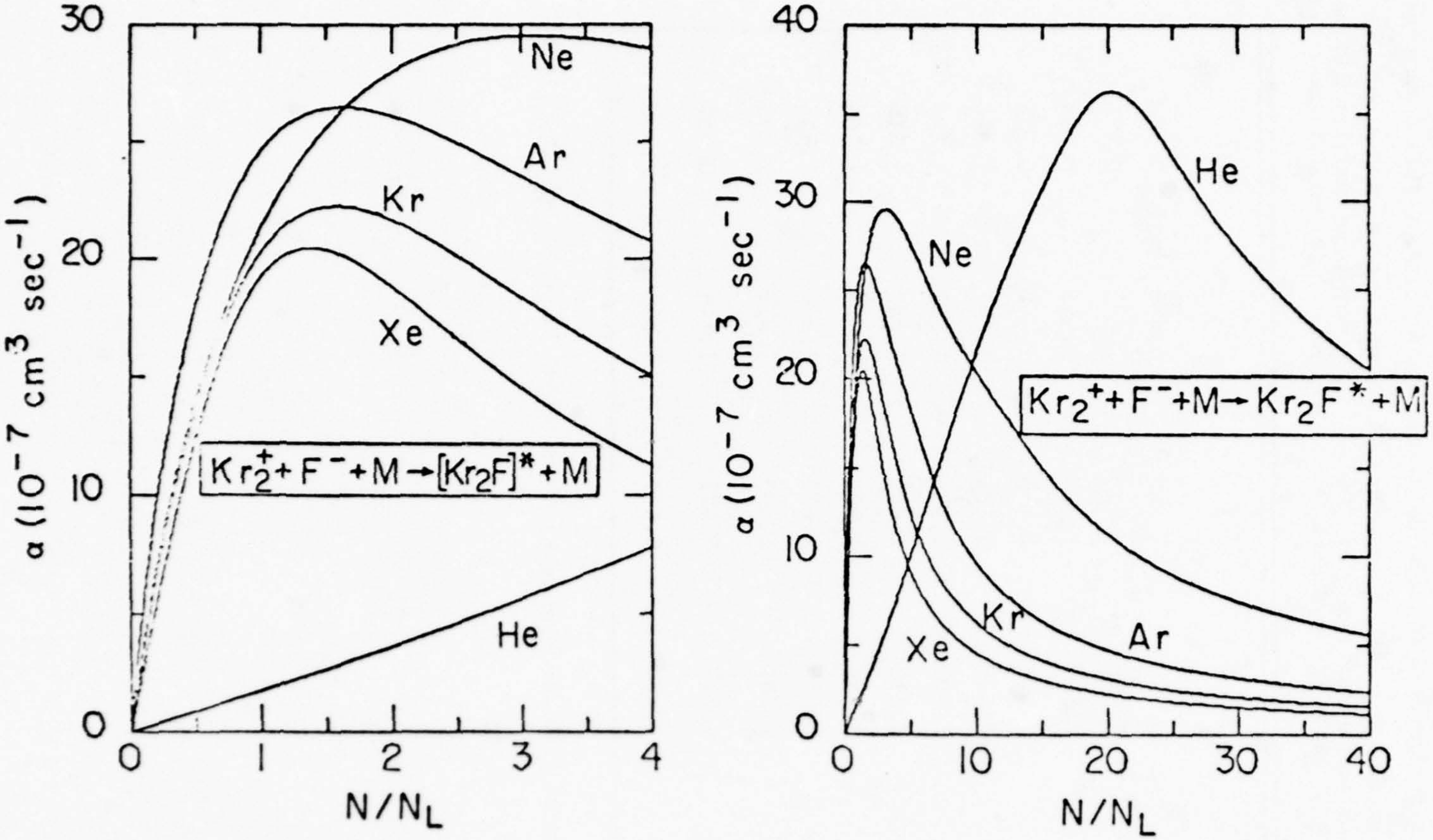
N/N_L [a]	He	Ne	Ar	Xe
0.1	1.675^{-2} [b]	3.755^{-1}	5.403^{-1}	2.795^{-1}
0.2	3.362^{-2}	6.890^{-1}	9.564^{-1}	5.408^{-1}
0.4	6.770^{-2}	1.190	1.566	1.020
0.6	1.023^{-1}	1.577	1.984	1.423
0.8	1.374^{-1}	1.884	2.268	1.727
1.0	1.731^{-1}	2.131	2.455	1.922
1.2	2.093^{-1}	2.331	2.568	2.021
1.4	2.461^{-1}	2.491	2.627	2.045 [c]
1.6	2.836^{-1}	2.620	2.648 [c]	2.017
1.8	3.216^{-1}	2.722	2.640	1.956
2.0	3.602^{-1}	2.800	2.612	1.877
2.2	3.994^{-1}	2.859	2.572	1.789
2.4	4.392^{-1}	2.902	2.522	1.699
2.6	4.796^{-1}	2.931	2.468	1.610
2.8	5.206^{-1}	2.948	2.411	1.525
3.0	5.021^{-1}	2.956 [c]	2.353	1.445
3.5	6.682^{-1}	2.942	2.210	1.268
4.0	7.774^{-1}	2.895	2.073	1.122
4.5	8.893^{-1}	2.829	1.943	1.003
5	1.003	2.752	1.818	9.051^{-1}
6	1.236	2.587	1.582	7.552^{-1}
7	1.472	2.425	1.375	6.471^{-1}
8	1.705	2.278	1.205	5.659^{-1}
9	1.931	2.146	1.069	5.029^{-1}
10	2.148	2.027	9.596^{-1}	4.524^{-1}
20	3.622 [c]	1.120	4.749^{-1}	2.261^{-1}
30	2.736	7.421^{-1}	3.162^{-1}	1.507^{-1}
40	2.043	5.553^{-1}	2.371^{-1}	1.130^{-1}
50	1.632	4.409^{-1}	1.896^{-1}	9.043^{-2}
α_0	1.670^{-1}	4.145	6.277	2.928
α_∞	8.152^{1}	2.219^{1}	9.481	4.522

[a] N_L is Loschmidt's number ($2.69\ 10^{19}\ cm^{-3}$), the number density of STP.

[b] The exponent denotes the power of ten by which the entry is to be multiplied.

[c] Indicates peak value.

Reference: M. R. Flannery and T. P. Yang, Appl. Phys. Letts., 33, 574 (1978).

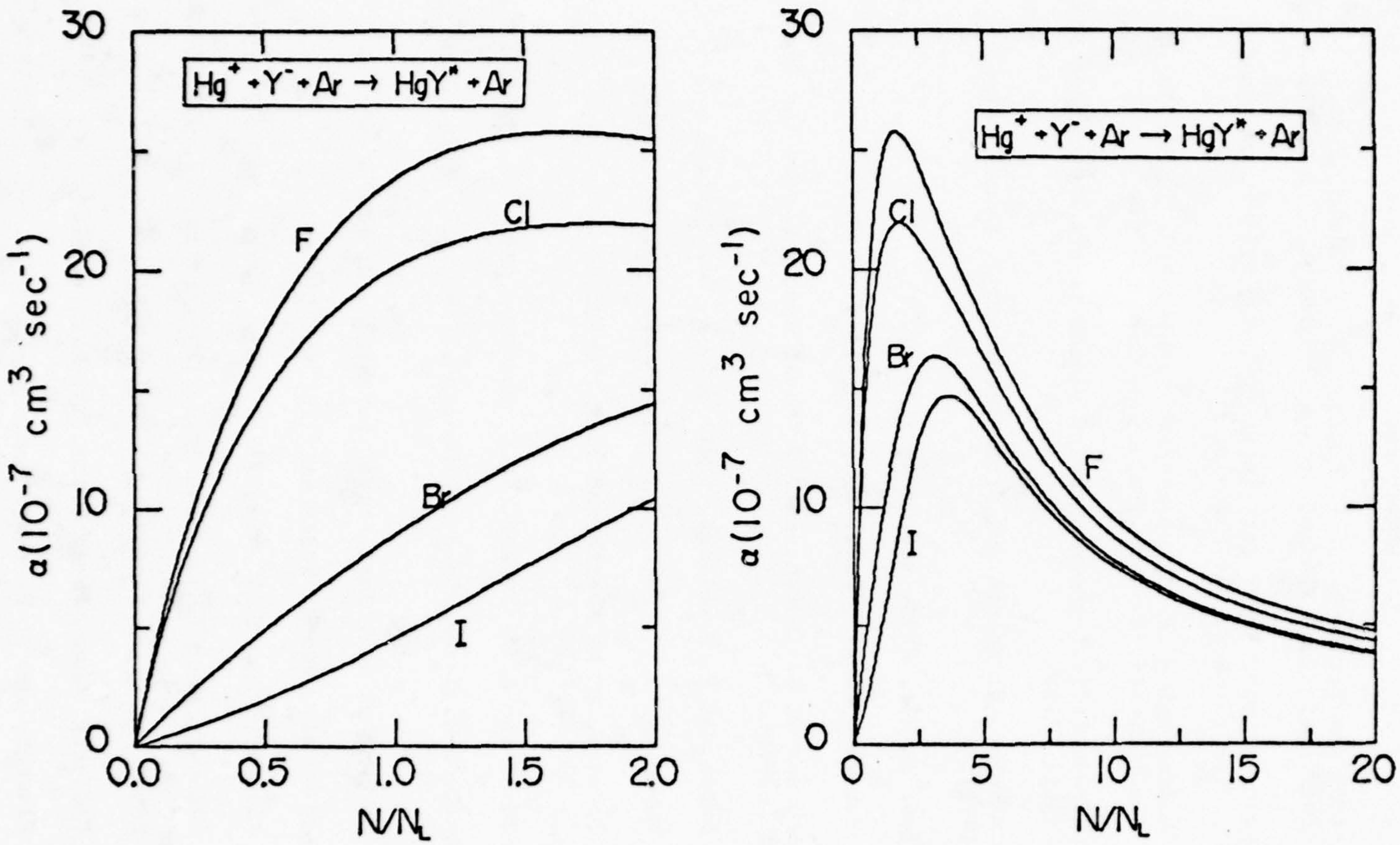


Graphical Data B-1.A-25. Ionic recombination coefficients $\alpha(cm^3\ sec^{-1})$ at 300°K for $Kr_2^+ + F^- + M \rightarrow [Kr_2^+F^-]^* + M$ ($M \equiv$ He, Ne, Ar, Kr, Xe) as a function of neutral gas density N (in units of Loschmidt's number N_L, $2.69 \times 10^{19}\ cm^{-3}$). Buffer gas M is as indicated on each curve. The square brackets indicate that the product molecule may not remain bound. (Tabular data were presented on the previous page.)

Tabular Data B-1.A-26. Three-body recombination rates $\alpha(10^{-6}\ cm^3\ sec^{-1})$ for the process $Hg^+ + Y^- + Ar \rightarrow HgY^* + Ar$ and $Y^- \equiv F^-, C\ell^-, Br^-, I^-$, for various gas densities N at 300°K. Low- and high-density limits are $\alpha_0(N/N_L)$ and $\alpha_\infty(N_L/N)$.

N/N_L	F^-	$C\ell^-$	Br^-	I^-
0.5	1.727	1.485	0.488	0.198
1.0	2.380	2.013	0.887	0.456
1.4	2.557	2.163	1.153	0.694
1.8	2.573	2.195	1.360	0.934
2.0	2.548	2.184	1.441	1.046
2.4	2.461	2.136	1.557	1.237
3.0	2.295	2.031	1.632	1.416
3.5	2.156	1.935	1.624	1.469
4.0	2.025	1.837	1.574	1.456
5.0	1.787	1.633	1.415	1.335
α_0	5.947	5.427	1.144	0.388
α_∞	9.380	8.547	7.696	7.460

Reference: M. R. Flannery, Chem. Phys. Letts. 56, 143 (1978).



Graphical Data B-1.A-27. Three-body ion-ion recombination coefficients $\alpha(cm^3\ sec^{-1})$ for the processes $Hg^+ + Y^- + Ar \rightarrow HgY^* + Ar$ ($Y^- \equiv F^-$, $C\ell^-$, Br^-, I^-) as a function of neutral-gas density N (in units of Loschmidt's number N_L, $2.69 \times 10^{19}\ cm^{-3}$). Negative ion is denoted on each curve. (Tabular data were presented on the previous page.)

References

1. Taken from the review by J. T. Moseley, R. E. Olson, and J. R. Peterson. Case Studies in Atomic Physics 5, 1 (1975).

2. J. Moseley et al., Phys. Rev. Letts. 24, 435 (1970). R. Rundel et al., J. Phys. B 2, 954 (1969).

3. T. D. Gailey and M. F. A. Harrison, J. Phys. B 3, 1098 (1970). R. E. Olson et al., J. Chem. Phys. 53, 3391 (1970).

4. M. A. Biondi (private communication quoted in NRL Memorandum Report 3753, April, 1978).

5. J. T. Moseley, W. Aberth and J. R. Peterson, J. Geophys. Res. 77, 255 (1972).

6. J. Weiner et al., Phys. Rev. A 4, 1825 (1971).

7. J. R. Peterson et al., Phys. Rev. A 3, 1651 (1971).

8. D. Smith and M. J. Church, Int. J. Mass. Spectrom. and Ion Physics 19, 185 (1976).

9. M. N. Hirsh and P. N. Eisner, Radio Sci. 7, 125 (1972).

10. B. H. Mahan and J. C. Person, J. Chem. Phys. 40, 392 (1964).

11. J. T. Moseley, W. H. Aberth, and J. R. Peterson, J. Geophys. Res. 77, 255 (1972).

12. M. N. Hirsh and P. N. Eisner, Bull. Am. Phys. Soc. 17, 395 (1972).

13. M. Rokni, J. H. Jacob, and J. A. Mangano, Phys. Rev. A 16, 2216 (1977).

14. J. A. Mangano et al., Appl. Phys. Letts. 31, 26 (1977).

15. D. Smith et al., Planet Space Sci. 24, 697 (1976).

16. M. R. Flannery, and T. P. Yang, Appl. Phys. Letts. 32, 327 (1978).

17. M. R. Flannery, and T. P. Yang, Appl. Phys. Letts. 32, 356 (1978).

18. D. R. Bates and M. R. Flannery, J. Phys. B 2, 184 (1969).

19. M. R. Flannery, Chem. Phys. Letts. 56, 143 (1978).

20. M. R. Flannery and T. P. Yang, Appl. Phys. Letts. 33, 574 (1978).

Section B-1.B. ION-MOLECULE REACTIONS*

CONTENTS

General References:

1. P. Ausloos (Editor), "Interactions Between Ions and Molecules," Plenum, New York (1975).

2. P. Ausloos (Editor), "Kinetics of Ion-Molecule Reactions," Plenum, New York (1979).

3. M. H. Bortner and T. Baurer (Editors), "Defense Nuclear Agency Reaction Rate Handbook" (Second Edition), DNA 1948-H (1972). Also see supplements published since 1972.

4. M. T. Bowers (Editor), "Ion-Molecule Reactions," Academic Press, New York (1979).

5. M. T. Bowers and J. B. Laudenslager, "Thermal Energy Ion-Molecule Interactions," in G. Bekefi (Editor), "Principles of Laser Plasmas," 90, Wiley, New York (1976).

6. M. T. Bowers and T. Su, "Thermal Energy Ion-Molecule Reactions," in L. Marton (Editor),"Advances in Electronics and Electron Physics," 34, 223, Academic, New York (1973).

7. J. V. Dugan, Jr. and J. L. Magee, "Dynamics of Ion-Molecule Collisions," in I. Prigogine (Editor), "Advances in Chemical Physics," 21, 207 (1971).

8. E. E. Ferguson, "Ion-Molecule Reactions," in H. Eyring (Editor), "Annual Review of Physical Chemistry," 26, 17, Annual Reviews, Inc., Palo Alto, California (1975).

9. J. L. Franklin (Editor), "Ion-Molecule Reactions," (2 Volumes), Plenum, New York (1972).

10. H. S. W. Massey, "Negative Ions" (Third Edition), Cambridge University Press, New York (1976).

---

*See also Section B-1, Vol. 1 and Section B-1.D of this volume.

11. E. W. McDaniel and E. A. Mason, "The Mobility and Diffusion of Ions in Gases," Wiley, New York (1973).

12. E. W. McDaniel, V. Čermák, A. Dalgarno, E. E. Ferguson, and L. Friedman, "Ion-Molecule Reactions," Wiley, New York (1970).

13. L. W. Sieck and S. G. Lias, "Rate Coefficients for Ion-Molecule Reactions, I. Ions Containing C and H," Jour. Phys. Chem. Ref. Data 5, 1123-1146 (1976).

Data Needed: The most pressing needs are for (1) rate coefficients for reactants in known excited states and (2) information concerning the states of excitation in which reaction products are formed.

Comments on Data Presented Here

The following data were selected from the compilation "Ion-Neutral Reaction-Rate Constants Measured in Flow Reactors Through 1977", bv D. L. Albritton, Atomic Data and Nuclear Data Tables 22, 1-101 (1978). The Albritton compilation lists approximately 1600 ion-molecule reaction measurements made with flowing afterglow, flow drift, and selected ion-flow tubes. The rate constants measured in flow reactors constitute a sizable fraction of all measured ion-neutral rate constants. Some of the data were available in 1977 but published in 1978. Albritton's paper contains references, error estimates, and other information not presented here. The accuracies are typically approximately ± 30%. (See Section B-1.C for additional data.)

Explanation of Table

Reaction: Clustered, excited-state, and doubly-charged ions are listed after normal ions. When given, product ions were generally observed. Product neutrals were generally not observed.

Rate Constant: Bimolecular (k) $A^+ + B \rightarrow C^+ + D$ — cm^3/(molecule·sec), abbreviated as cm^3/sec

$$\frac{d[A^+]}{dt} = -k[A^+][B]$$

Termolecular (k) $A^+ + B + M \rightarrow C^+ + D + M$ — cm^6/(molecule^2·sec), abbreviated as cm^6/sec

$$\frac{d[A^+]}{dt} = -k[A^+][B][M]$$

When two or more product channels occur, the tabulated rate constant refers to the total rate into all product channels. Furthermore, when the reaction has been studied over a range of temperatures or kinetic energies, the tabulated rate constant refers to 300°K (or 0.04 eV) if the range includes room temperature or to the temperature or energy nearest 300°K if the range does not include room temperature.

Product Ratio: $k_i/\Sigma k_i$, where Σk_i corresponds to the tabulated total rate constant.

Energy Range: 82-290, 300 etc. Temperature in °K
0.14-2.0, etc. Relative kinetic energy in eV.

The tabulated energy range expresses the limits over which the reaction was studied. For temperature, these limits generally imply that a few intermediate temperatures were also used, but not always. For mean relative kinetic energy, many intermediate values were generally examined. Furthermore, the mean relative kinetic energy is that calculated for an ion-speed distribution that may sometimes differ significantly from a Maxwellian speed distribution.

Tabular Data B-1.B-1. Rate coefficients of ion-molecule reactions (positive ions).

Reaction	Positive Ions Rate Constant (cm^3/sec; cm^6/sec)	Product Ratio (%)	Energy (^oK, eV)
$Ar^+ + Ar + He \rightarrow Ar_2^+ + He$	1×10^{-31}		82 - 290
$Ar^+ + CO \rightarrow CO^+ + Ar$	9×10^{-11}		300
$Ar^+ + CO_2 \rightarrow CO_2^+ + Ar$	7.6×10^{-10}		300
$Ar^+ + H_2 \rightarrow ArH^+ + H$	7.4×10^{-10}		82 - 506
$Ar^+ + H_2O \rightarrow ArH^+ + HO$	1.43×10^{-9}		296
$Ar^+ + N_2 \rightarrow N_2^+ + Ar$	7×10^{-12}		280
$Ar^+ + O_2 \rightarrow O_2^+ + Ar$	5.2×10^{-11}		300
$Ar^+ + O_2 \rightarrow O_2^+ + Ar$	4.6×10^{-11}		82 - 506
$C^+ + CO \rightarrow$ products	$\leq 5 \times 10^{-13}$		300
$C^+ + CO_2 \rightarrow CO^+ + CO$	1.1×10^{-9}		300
$C^+ + H_2 \rightarrow$ products	$\leq 5 \times 10^{-13}$		300
$C^+ + H_2 + He \rightarrow CH_2^+ + He$	2.1×10^{-29}		90
$C^+ + H_2O \rightarrow CHO^+ + H$	2.5×10^{-9}		300
$C^+ + N_2 \rightarrow$ products	$\leq 5 \times 10^{-13}$		300
$C^+ + N_2O \rightarrow NO^+ + CN$	9.1×10^{-10}		300
$C^+ + O_2 \rightarrow CO^+ + O$	9.9×10^{-10}	38	300
$CH^+ + CO \rightarrow CHO^+ + C$	7×10^{-12}		300
$CH^+ + CO_2 \rightarrow CHO^+ + CO$	1.6×10^{-9}		300
$CH^+ + H_2 \rightarrow CH_2^+ + H$	1.2×10^{-9}		300
$CH^+ + H_2O \rightarrow CHO^+ + H_2$	2.9×10^{-9}		300
$CO^+ + CH_2O \rightarrow CHO^+ + CHO$	3.0×10^{-9}	55	300
$CO^+ + CO_2 \rightarrow CO_2^+ + CO$	1.0×10^{-9}		300
$CO^+ + H_2 \rightarrow CHO^+ + H$	1.8×10^{-9}		300
$CO^+ + H_2O \rightarrow H_2O^+ + CO$	2.2×10^{-9}		300
$CO^+ + N \rightarrow NO^+ + C$	$\leq 2 \times 10^{-11}$		300
$CO^+ + NO \rightarrow NO^+ + CO$	3.3×10^{-10}		300

Tabular Data B-1.B-1. (Continued).

Reaction	Positive Ions Rate Constant (cm^3/sec; cm^6/sec)	Product Ratio (%)	Energy (^oK, eV)
$CO^+ + N_2 \rightarrow$ products	$\leq 4 \times 10^{-14}$		300
$CO^+ + O \rightarrow O^+ + CO$	1.4×10^{-10}		300
$CO^+ + O_2 \rightarrow O_2^+ + CO$	1.2×10^{-10}		300
$CO_2^+ + H \rightarrow CHO^+ + O$	6×10^{-10}	83	300
$CO_2^+ + H_2 \rightarrow CHO_2^+ + H$	1.4×10^{-9}		300
$CO_2^+ + N \rightarrow$ products	$\leq 1 \times 10^{-11}$		295
$CO_2^+ + NO \rightarrow NO^+ + CO_2$	1.2×10^{-10}		295
$CO_2^+ + O \rightarrow O^+ + CO_2$	2.6×10^{-10}	37	295
$CO_2^+ + O_2 \rightarrow O_2^+ + CO_2$	5.6×10^{-11}		0.04 - 2.0
$CO_2^+ + O_2 \rightarrow O_2^+ + CO_2$	6.4×10^{-11}		300 - 870
$C_2^+ + H_2 \rightarrow C_2H^+ + H$	1.4×10^{-9}		300
$Cl^+ + H_2 \rightarrow ClH^+ + H$	7.1×10^{-10}		297
$Cl^+ + O_2 \rightarrow O_2^+ + Cl$	4.6×10^{-10}		300
$ClH^+ + H_2 \rightarrow ClH_2^+ + H$	5.2×10^{-10}		297
$Fe^+ + O_2 + Ar \rightarrow FeO_2^+ + Ar$	1.0×10^{-30}		300
$Fe^+ + O_3 \rightarrow FeO^+ + O_2$	1.5×10^{-10}		300
$H^+ + CO_2 \rightarrow CHO^+ + O$	3×10^{-9}		300
$H^+ + NO \rightarrow NO^+ + H$	1.9×10^{-9}		300
$H^+ + O \rightarrow O^+ + H$	3.75×10^{-10}		300
$HHe^+ + H_2 \rightarrow$ products	$\geq 3.5 \times 10^{-11}$		200
$HHe^+ + N_2 \rightarrow HN_2^+ + He$	1.7×10^{-9}		300
$HHe_2^+ + H_2 \rightarrow$ products	3.0×10^{-10}		200
$HN^+ + H_2 \rightarrow H_2N^+ + H$	1×10^{-9}		300
$HN^+ + N_2 \rightarrow HN_2^+ + N$	1×10^{-9}		300
$HNe^+ + H_2 \rightarrow$ products	2.0×10^{-11}		200
$HNe_2^+ + H_2 \rightarrow$ products	9.6×10^{-11}		200

Table B-1.B-1. (Continued).

Reaction	Rate Constant (cm^3/sec; cm^6/sec)	Product Ratio (%)	Energy (^oK, eV)
Positive Ions			
$HO^+ + H_2 \rightarrow H_2O^+ + H$	1.5×10^{-9}		300
$HO^+ + O_2 \rightarrow O_2^+ + HO$	2×10^{-10}		300
$HO_2^+ + Ar \rightarrow ArH^+ + O_2$	1.9×10^{-11}		0.21 - 2.1
$HO_2^+ + CO_2 \rightarrow CHO_2^+ + O_2$	1.1×10^{-9}		0.04 - 2.0
$HO_2^+ + H_2 \rightarrow H_3^+ + O_2$	3.0×10^{-10}		0.04 - 0.2
$HO_2^+ + NO \rightarrow HNO^+ + O_2$	7.3×10^{-10}		0.05 - 1.2
$HO_2^+ + N_2 \rightarrow HN_2^+ + O_2$	8.0×10^{-10}		0.04 - 1.5
$H_2He^+ + H_2 \rightarrow$ products	$\geq 2.4 \times 10^{-11}$		200
$H_2N^+ + H_2 \rightarrow H_3N^+ + H$	1×10^{-9}		300
$H_2Ne^+ + H_2 \rightarrow$ products	$\leq 4.0 \times 10^{-13}$		200
$H_2O^+ + H_2 \rightarrow H_3O^+ + H$	1.4×10^{-9}		300
$H_2O^+ + H_2O \rightarrow$ products	1.67×10^{-9}		300
$H_2O^+ + O_2 \rightarrow O_2^+ + H_2O$	2×10^{-10}		300
$H_2O_2^+ + CO \rightarrow CHO^+ + HO_2$	5.5×10^{-11}		0.2 - 1.4
$H_2O_2^+ + H_2O \rightarrow H_3O^+ + HO_2$	1.7×10^{-9}		0.04 - 0.5
$H_2O_2^+ + NO \rightarrow NO^+ + H_2O_2$	5.0×10^{-10}		0.04 - 1.3
$H_3^+ + Ar \rightarrow ArH^+ + H_2$	$\leq 1 \times 10^{-11}$		300
$H_3^+ + Ar + Ar \rightarrow ArH_3^+ + Ar$	1×10^{-31}		300
$H_3^+ + Ar + H_2 \rightarrow ArH_3^+ + H_2$	1×10^{-31}		300
$H_3^+ + CO \rightarrow CHO^+ + H_2$	1.4×10^{-9}		300
$H_3^+ + CO_2 \rightarrow CHO_2^+ + H_2$	1.9×10^{-9}		300
$H_3^+ + H_2O \rightarrow H_3O^+ + H_2$	4.3×10^{-9}		297
$H_3^+ + NO \rightarrow HNO^+ + H_2$	1.4×10^{-9}		300
$H_3^+ + NO_2 \rightarrow NO^+ + HO + H_2$	7×10^{-10}		300
$H_3^+ + N_2 \rightarrow HN_2^+ + H_2$	2.0×10^{-9}		300
$H_3^+ + N_2O \rightarrow HN_2O^+ + H_2$	1.8×10^{-9}		300

Table B-1.B-1. (Continued).

Positive Ions Reaction	Rate Constant (cm^3/sec; cm^6/sec)	Product Ratio (%)	Energy (^oK, eV)
$H_3^+ + O \rightarrow$ products	8.0×10^{-10}		300
$H_3^+ + O_2 \rightarrow HO_2^+ + H_2$	7.0×10^{-10}		0.04 - 0.6
$H_3^+ + O_2 + H_2 \rightarrow H_3O_2^+ + H_2$	3×10^{-29}		300
$H_3O^+ + H_2 \rightarrow$ products	$\leq 5 \times 10^{-15}$		300
$H_3O^+ + H_2O + H_2 \rightarrow H_3O^+ \cdot H_2O + H_2$	5×10^{-27}		300
$H_3O^+ + H_2O + He \rightarrow H_3O^+ \cdot H_2O + He$	6.65×10^{-28}		296
$He^+ + Ar \rightarrow Ar^+ + He$	$\leq 1 \times 10^{-13}$		300
$He^+ + CO \rightarrow C^+ + He + O$	1.7×10^{-9}		300
$He^+ + CO_2 \rightarrow CO^+ + He + O$	1.1×10^{-9}	79	300
$He^+ + H_2 \rightarrow$ products	$\leq 1 \times 10^{-13}$		300
$He^+ + H_2O \rightarrow HHe^+ + HO$	4.5×10^{-10}		300
$He^+ + Kr \rightarrow$ products	$\leq 1 \times 10^{-11}$		300
$He^+ + NO \rightarrow N^+ + He + O$	1.5×10^{-9}		300
$He^+ + N_2 \rightarrow N^+ + He + N$	1.6×10^{-9}	60	300
$He^+ + N_2(v) \rightarrow N^+ + He + N$		70	300
$He^+ + O_2 \rightarrow O^+ + He + O$	1.1×10^{-9}	97	300
$He^+ + Xe \rightarrow$ products	7×10^{-12}		300
$HeNe^+ + Ne \rightarrow Ne_2^+ + He$	1.4×10^{-10}		200
$He_2^+ + Ar \rightarrow Ar^+ + 2He$	2.0×10^{-10}		200
$He_2^+ + CO \rightarrow CO^+ + 2He$	1.4×10^{-9}		200
$He_2^+ + CO_2 \rightarrow CO^+ + 2He + O$	1.8×10^{-9}		200
$He_2^+ + H_2 \rightarrow$ products	5.3×10^{-10}		200
$He_2^+ + Kr \rightarrow Kr^+ + 2He$	1.85×10^{-11}		200
$He_2^+ + NO \rightarrow NO^+ + 2He$	1.3×10^{-9}		200
$He_2^+ + N_2 \rightarrow N_2^+ + 2He$	1.2×10^{-9}		300 - 870
$He_2^+ + Ne \rightarrow Ne^+ + 2He$	6.0×10^{-10}		200

Table B-1.B-1. (Continued).

Positive Ions			
Reaction	Rate Constant (cm^3/sec; cm^6/sec)	Product Ratio (%)	Energy (^oK, eV)
$He_2^+ + Ne \rightarrow Ne^+ + 2He$	1.4×10^{-10}		300
$He_2^+ + O_2 \rightarrow O^+ + 2He + O$	1.05×10^{-9}		200
$Kr^+ + H_2 \rightarrow HKr^+ + H$	2.01×10^{-10}		297
$Kr^+ + H_2O \rightarrow H_2O^+ + Kr$	1.19×10^{-9}		296
$N^+ + CO \rightarrow CO^+ + N$	4.5×10^{-10}	88	300
$N^+ + CO_2 \rightarrow CO^+ + NO$	1.0×10^{-9}	25	300
$N^+ + F_6S \rightarrow F_5S^+ + FN$	1.4×10^{-9}		300
$N^+ + H_2 \rightarrow HN^+ + H$	4.8×10^{-10}		300
$N^+ + H_2O \rightarrow H_2O^+ + N$	2.8×10^{-9}		300
$N^+ + NO \rightarrow NO^+ + N$	9×10^{-10}		300
$N^+ + N_2 + He \rightarrow N_3^+ + He$	8.6×10^{-30}		82 - 280
$N^+ + N_2 + He + N_2 \rightarrow N_3^+ + He + N_2$	5.2×10^{-30}		300
$N^+ + O_2 \rightarrow NO^+ + O$	6.1×10^{-10}	43	300
$NO^+ + CO_2 + Ar \rightarrow NO^+ \cdot CO_2 + Ar$	5.0×10^{-30}		300
$NO^+ + CO_2 + Ar \rightarrow NO^+ \cdot CO_2 + Ar$	2.4×10^{-29}		196 - 214
$NO^+ + CO_2 + He \rightarrow NO^+ \cdot CO_2 + He$	4.5×10^{-30}		300
$NO^+ + CO_2 + He \rightarrow NO^+ \cdot CO_2 + He$	4×10^{-30}		197 - 290
$NO^+ + CO_2 + N_2 \rightarrow NO^+ \cdot CO_2 + N_2$	9.5×10^{-30}		225 - 300
$NO^+ + H_2 \rightarrow$ products	$\leq 1 \times 10^{-13}$		300
$NO^+ + H_2O + Ar \rightarrow NO^+ \cdot H_2O + Ar$	7.8×10^{-29}		295
$NO^+ + H_2O + He \rightarrow NO^+ \cdot H_2O + He$	3.6×10^{-29}		295
$NO^+ + H_2O + N_2 \rightarrow NO^+ \cdot H_2O + N_2$	1.6×10^{-28}		295
$NO^+ + H_2O + O_2 \rightarrow NO^+ \cdot H_2O + O_2$	8.6×10^{-29}		296
$NO^+ + N_2 + He \rightarrow NO^+ \cdot N_2 + He$			80 - 296
$NO^+ + N_2 + N_2 \rightarrow NO^+ \cdot N_2 + N_2$	$\leq 1.0 \times 10^{-30}$		225 - 300
$NO^+ + O_2 + N_2 \rightarrow NO^+ \cdot O_2 + N_2$	3×10^{-31}		225 - 300

Table B-1.B-1. (Continued).

Reaction	Rate Constant (cm^3/sec; cm^6/sec)	Product Ratio (%)	Energy (^oK, eV)
	Positive Ions		
$NO^+ + O_3 \rightarrow NO_2^+ + O_2$	$\leq 1 \times 10^{-14}$		300
$NO^+ \cdot N_2 + He \rightarrow NO^+ + N_2 + He$			80 - 296
$NO^+ \cdot O_2 + Ar \rightarrow NO^+ + O_2 + Ar$			200
$NO^+ \cdot O_2 + He \rightarrow NO^+ + O_2 + He$			200
$NO_2^+ + N \rightarrow NO^+ + NO$	$\leq 8 \times 10^{-12}$		296
$NO_2^+ + O \rightarrow NO^+ + O_2$	$\leq 8 \times 10^{-12}$		296
$N_2^+ + CO \rightarrow CO^+ + N_2$	7.4×10^{-11}		300
$N_2^+ + CO_2 \rightarrow CO_2^+ + N_2$	7.7×10^{-10}		300
$N_2^+ + H_2 \rightarrow HN_2^+ + H$	2.1×10^{-9}		300
$N_2^+ + H_2O \rightarrow HN_2^+ + HO$	2.8×10^{-9}	18	300
$N_2^+ + N \rightarrow N^+ + N_2$	$\leq 1 \times 10^{-11}$		300
$N_2^+ + NO \rightarrow NO^+ + N_2$	3.3×10^{-10}		295
$N_2^+ + N_2 + He \rightarrow N_4^+ + He$	1.9×10^{-29}		82 - 280
$N_2^+ + N_2O \rightarrow N_2O^+ + N_2$	7.0×10^{-10}		300
$N_2^+ + O \rightarrow NO^+ + N$	1.4×10^{-10}	≥ 96	295
$N_2^+ + O_2 \rightarrow O_2^+ + N_2$	5.1×10^{-11}		300
$N_3^+ + CO + He + N_2 \rightarrow N_3^+ \cdot CO + He + N_2$	7×10^{-29}		300
$N_3^+ + CO_2 \rightarrow$ products	$\leq 5 \times 10^{-14}$		300
$N_3^+ + H_2 \rightarrow HN_2^+ + HN$	2×10^{-13}		300
$N_3^+ + H_2O \rightarrow H_2NO^+ + N_2$	3.3×10^{-10}		300
$N_3^+ + NO \rightarrow NO^+ + N + N_2$	1.4×10^{-10}		0.04 - 0.3
$N_3^+ + O_2 \rightarrow NO^+ + N_2O$	5.1×10^{-11}	70	300
$N_4^+ + CO \rightarrow CO^+ + 2N_2$	5×10^{-10}		300
$N_4^+ + CO_2 \rightarrow CO_2^+ + 2N_2$	7.0×10^{-10}		300
$N_4^+ + H_2 \rightarrow HN_2^+ + H + N_2$	5.8×10^{-12}	87	300
$N_4^+ + H_2O \rightarrow H_2O^+ + 2N_2$	3.0×10^{-9}		300

Table B-1.B-1. (Continued).

Reaction	Positive Ions Rate Constant (cm^3/sec; cm^6/sec)	Product Ratio (%)	Energy (°K, eV)
$N_4^+ + O_2 \rightarrow O_2^+ + 2N_2$	2.5×10^{-10}		300
$Ne^+ + CO \rightarrow$ products	$\leq 1 \times 10^{-13}$		300
$Ne^+ + CO_2 \rightarrow$ products	5×10^{-11}		300
$Ne^+ + H_2 \rightarrow$ products	$\leq 3 \times 10^{-13}$		300
$Ne^+ + H_2O \rightarrow HO^+ + H + Ne$	8.2×10^{-10}		300
$Ne^+ + NO \rightarrow N^+ + Ne + O$	1.2×10^{-10}		300
$Ne^+ + N_2 \rightarrow$ products	$\leq 1 \times 10^{-12}$		300
$Ne^+ + N_2(v=2) \rightarrow N_2^+ + Ne$	2.3×10^{-10}		300
$Ne^+ + O_2 \rightarrow O^+ + O + Ne$	5.5×10^{-11}		300
$Ne^+ + Xe \rightarrow$ products	$\leq 5 \times 10^{-13}$		300
$Ne_2^+ + Ar \rightarrow Ar^+ + 2Ne$	$\leq 5 \times 10^{-14}$		200
$Ne_2^+ + CO \rightarrow CO^+ + 2Ne$	5.1×10^{-10}		200
$Ne_2^+ + CO_2 \rightarrow CO^+ + 2Ne + O$	1.1×10^{-9}		200
$Ne_2^+ + H_2 \rightarrow$ products	1.1×10^{-10}		200
$Ne_2^+ + Kr \rightarrow Kr^+ + 2Ne$	$\leq 5 \times 10^{-13}$		200
$Ne_2^+ + NO \rightarrow NO^+ + 2Ne$	7.0×10^{-10}		200
$Ne_2^+ + N_2 \rightarrow N_2^+ + 2Ne$	9.1×10^{-10}		200
$Ne_2^+ + O_2 \rightarrow O^+ + 2Ne + O$	7.1×10^{-10}		200
$O^+ + CO \rightarrow$ products	$\leq 5 \times 10^{-13}$		300
$O^+ + CO_2 \rightarrow CO_2^+ + O$	9.0×10^{-10}		300 - 870
$O^+ + H_2 \rightarrow HO^+ + H$	1.7×10^{-9}		300
$O^+ + H_2O \rightarrow H_2O^+ + O$	3.2×10^{-9}		300
$O^+ + NO \rightarrow NO^+ + O$	1.7×10^{-12}		0.2 - 3.5
$O^+ + NO \rightarrow NO^+ + O$	$\leq 8 \times 10^{-13}$		300
$O^+ + NO_2 \rightarrow NO_2^+ + O$	1.6×10^{-9}		393
$O^+ + N_2 \rightarrow NO^+ + N$	1.2×10^{-12}		300

Table B-1.B-1. (Continued).

Reaction	Rate Constant (cm^3/sec; cm^6/sec)	Product Ratio (%)	Energy (^oK, eV)
Positive Ions			
$O^+ + N_2(v) \rightarrow NO^+ + N$	1.3×10^{-12}		300
$O^+ + N_2 + He \rightarrow NO^+ + N + He$	5.4×10^{-29}		82
$O^+ + N_2O \rightarrow NO^+ + NO$	6.3×10^{-10}		393
$O^+ + O_2 \rightarrow O_2^+ + O$	1.9×10^{-11}		300
$O_2^+ + CO_2 + He \rightarrow O_2^+ \cdot CO_2 + He$	2.3×10^{-29}		200
$O_2^+ + H_2 \rightarrow$ products	$\leq 1 \times 10^{-11}$		300
$O_2^+ + H_2 + He \rightarrow O_2^+ \cdot H_2 + He$	7.4×10^{-31}		80
$O_2^+ + H_2O + Ar \rightarrow O_2^+ \cdot H_2O + Ar$	2.0×10^{-28}		295
$O_2^+ + H_2O + He \rightarrow O_2^+ \cdot H_2O + He$	9×10^{-29}		295
$O_2^+ + H_2O + N_2 \rightarrow O_2^+ \cdot H_2O + N_2$	2.8×10^{-28}		295
$O_2^+ + H_2O + O_2 \rightarrow O_2^+ \cdot H_2O + O_2$	2.3×10^{-28}		296
$O_2^+ + N \rightarrow NO^+ + O$	1.2×10^{-10}		296
$O_2^+ + NO \rightarrow NO^+ + O_2$	4.4×10^{-10}		0.04 - 1.1
$O_2^+ + N_2 \rightarrow NO^+ + NO$	$\leq 1 \times 10^{-15}$		600
$O_2^+ + N_2 \rightarrow NO^+ + NO$	$\leq 1 \times 10^{-15}$		300
$O_2^+ + N_2 + He \rightarrow O_2^+ \cdot N_2 + He$	1.9×10^{-29}		80
$O_2^+ + N_2 + N_2 \rightarrow O_2^+ \cdot N_2 + N_2$	8×10^{-31}		296
$O_2^+ + N_2O + He \rightarrow O_2^+ \cdot N_2O + He$	5.2×10^{-29}		200
$O_2^+ + O_2 + He \rightarrow O_4^+ + He$	2.4×10^{-30}		200
$O_2^+ + O_2 + O_2 \rightarrow O_4^+ + O_2$	2.5×10^{-30}		296
$O_2^+ + O_3 + He \rightarrow O_5^+ + He$	1×10^{-28}		200
$O_2^+(a\ ^4\Pi_u) + Ar \rightarrow Ar^+ + O_2$	5.0×10^{-10}		0.04 - 2.0
$O_2^+(a\ ^4\Pi_u) + CO \rightarrow CO^+ + O_2$	2.0×10^{-10}		0.04 - 2.0
$O_2^+(a\ ^4\Pi_u) + CO_2 \rightarrow CO_2^+ + O_2$	9.0×10^{-10}		0.04 - 2.0
$O_2^+(a\ ^4\Pi_u) + H_2 \rightarrow HO_2^+ + H$	1.2×10^{-9}		0.04 - 0.3
$O_2^+(a\ ^4\Pi_u) + NO \rightarrow NO^+ + O_2$	1.1×10^{-9}		0.05 - 1.5

Table B-1.B-1. (Concluded).

Reaction	Rate Constant (cm^3/sec; cm^6/sec)	Product Ratio (%)	Energy (^oK, eV)
Positive Ions			
$O_2^+(a\ ^4\Pi_u) + N_2 \rightarrow N_2^+ + O_2$	4.1×10^{-10}		0.04 - 2.0
$O_2^+(a\ ^4\Pi_u) + O_2 \rightarrow O_2^+ + O_2$	3.1×10^{-10}		0.05 - 2.0
$O_4^+ + CO_2 \rightarrow O_2^+\cdot CO_2 + O_2$			250 - 295
$O_4^+ + H_2O \rightarrow O_2^+\cdot H_2O + O_2$	2.2×10^{-9}		295
$O_4^+ + He \rightarrow O_2^+ + O_2 + He$	3.6×10^{-14}		296
$O_4^+ + N_2 + He \rightarrow O_4^+\cdot N_2 + He$	1.0×10^{-29}		80
$O_4^+ + N_2O \rightarrow O_2^+\cdot N_2O + O_2$	2.5×10^{-10}		200
$O_4^+ + O \rightarrow O_2^+ + O_3$	3×10^{-10}		295
$O_4^+ + O_2 \rightarrow O_2^+ + O_2 + O_2$	1.8×10^{-13}		296
$O_4^+ + O_2 + He \rightarrow O_6^+ + He$	5.0×10^{-30}		80
$O_4^+ + O_3 \rightarrow O_5^+ + O_2$			250 - 295
$O_5^+ + CO_2 \rightarrow O_2^+\cdot CO_2 + O_3$	$\leq 1 \times 10^{-11}$		200
$O_5^+ + H_2O \rightarrow O_2^+\cdot H_2O + O_3$	1.2×10^{-9}		300
$O_5^+ + O_2 \rightarrow O_4^+ + O_3$			250 - 295
$S^+ + CO_2 \rightarrow OS^+ + CO$	$\leq 1 \times 10^{-12}$		300
$S^+ + NO \rightarrow NO^+ + S$	4.2×10^{-10}		300
$S^+ + O_2 \rightarrow OS^+ + O$	1.6×10^{-11}		300

Tabular Data B-1.B-2. Rate coefficient of ion-molecule reactions (negative ions).

Reaction	Negative Ions Rate Constant (cm^3/sec; cm^6/sec)	Product Ratio (%)	Energy (^oK, eV)
$C^- + CO \rightarrow e + C_2O$	4.1×10^{-10}		300
$C^- + CO_2 \rightarrow e + 2CO$	4.7×10^{-11}		300
$C^- + H_2 \rightarrow e + CH_2$	$\leq 1 \times 10^{-13}$		300
$C^- + N_2O \rightarrow e +$ product(s)	9.0×10^{-10}		300
$C^- + O_2 \rightarrow e +$ product(s)	4.0×10^{-10}	$\leq$15	300
$CN^- + H \rightarrow e + CHN$	1.3×10^{-9}		296
$CO_3^- + H \rightarrow HO^- + CO_2$	1.7×10^{-10}		296
$CO_3^- + H_2O + O_2 \rightarrow CO_3^-{\cdot}H_2O + O_2$	1×10^{-28}		296
$CO_3^- + NO \rightarrow NO_2^- + CO_2$	1.1×10^{-11}		0.04 - 1.1
$CO_3^- + NO_2 \rightarrow NO_3^- + CO_2$	2×10^{-10}		296
$CO_3^- + N_2O \rightarrow CO_4^- + N_2$	$\leq 5 \times 10^{-13}$		298
$CO_3^- + O \rightarrow O_2^- + CO_2$	1.1×10^{-10}		300
$CO_3^- + O_2 \rightarrow O_3^- + CO_2$	$\leq 6 \times 10^{-15}$		595
$CO_3^-{\cdot}H_2O + NO \rightarrow NO_2 + CO_2 + H_2O$	7×10^{-12}		296
$CO_3^-{\cdot}H_2O + NO_2 \rightarrow NO_3^- + H_2O + CO_2$	1.5×10^{-10}		296
$CO_3^-{\cdot}H_2O + O_2 \rightarrow CO_3^- + H_2O + O_2$	3.3×10^{-14}		296
$CO_4^- + H \rightarrow CO_3^- + HO$	2.2×10^{-10}		296
$CO_4^- + H_2O \rightarrow O_2^-{\cdot}H_2O + CO_2$			296
$CO_4^- + NO \rightarrow NO_3^- + CO_2$	4.8×10^{-11}	$\leq$ 2	300
$CO_4^- + O \rightarrow CO_3^- + O_2$	1.4×10^{-10}		300
$CO_4^- + O_2 \rightarrow O_4^- + CO_2$			300
$CO_4^- + O_3 \rightarrow O_3^- + CO_2 + O_2$	1.3×10^{-10}		296
$C_2^- + CO \rightarrow e + C_3O$	$\leq 1 \times 10^{-12}$		298
$C_2^- + CO_2 \rightarrow e + C_3O_2$	$\leq 5 \times 10^{-13}$		298
$C_2^- + H_2 \rightarrow C_2H^- + H$	$\leq 1 \times 10^{-13}$		298
$C_2^- + H_2O \rightarrow e +$ product(s)	$\leq 1 \times 10^{-12}$		298

Tabular Data B-1.B-2. (Continued).

Negative Ions			
Reaction	Rate Constant (cm^3/sec; cm^6/sec)	Product Ratio (%)	Energy (^oK, eV)
$C_2^- + O_2 \rightarrow e + CO_2 + C$	2.1×10^{-11}		296
$C_2H^- + CO \rightarrow e + C_3HO$	$\leq 1 \times 10^{-12}$		298
$C_2H^- + CO_2 \rightarrow e + C_3HO_2$	$\leq 1 \times 10^{-13}$		298
$C_2H^- + CO_2 + He \rightarrow C_3HO_2^- + He$	observed		300
$C_2H^- + H_2 \rightarrow e + C_2H_3$	$\leq 1 \times 10^{-13}$		298
$C_2H^- + H_2O \rightarrow e + products$	$\leq 1 \times 10^{-12}$		298
$C_2H^- + H_2O \rightarrow HO^- + C_2H_2$	9.3×10^{-15}		296
$C_2H^- + N_2O \rightarrow products$	not observed		300
$Cl^- + H \rightarrow e + ClH$	9.3×10^{-10}		0.55 - 0.2
$Cl^- + H \rightarrow e + ClH$	9.6×10^{-10}		296
$Cl^- + H_2O + O_2 \rightarrow Cl^-\cdot H_2O + O_2$	2×10^{-29}		296
$Cl^- + N \rightarrow e + ClN$	$\leq 1 \times 10^{-11}$		300
$Cl^- + NO_2 \rightarrow NO_2^- + Cl$	$\leq 6 \times 10^{-12}$		300
$Cl^- + O \rightarrow e + ClO$	$\leq 1 \times 10^{-11}$		300
$Cl^- + O_3 \rightarrow ClO^- + O_2$	$\leq 5 \times 10^{-13}$		300
$Cl^-\cdot H_2O + H \rightarrow e + ClH + H_2O$	$\leq 8 \times 10^{-11}$		296
$Cl^-\cdot H_2O + H_2O + O_2 \rightarrow Cl^-\cdot 2H_2O + O_2$			296
$Cl^-\cdot H_2O + O_2 \rightarrow Cl^- + H_2O + O_2$	4.1×10^{-16}		296
$Cl^-\cdot 2H_2O + H \rightarrow e + ClH + 2H_2O$	$\leq 8 \times 10^{-11}$		296
$Cl^-\cdot 2H_2O + H_2O + O_2 \rightarrow Cl^-\cdot 3H_2O + O_2$			296
$Cl^-\cdot 2H_2O + O_2 \rightarrow Cl^-\cdot H_2O + H_2O + O_2$			296
$ClO^- + CO_2 \rightarrow products$	$\leq 1 \times 10^{-13}$		300
$ClO^- + NO \rightarrow NO_2^- + Cl$	2.9×10^{-11}		300
$ClO^- + NO_2 \rightarrow NO_2^- + ClO$	3.2×10^{-10}		300
$ClO^- + O_3 \rightarrow Cl^- + 2O_2$	7×10^{-11}	85	300
$Cl_2^- + NO_2 \rightarrow Cl^- + ClNO_2$	4×10^{-11}		280 - 500

Tabular Data B-1.B-2. (Continued).

Reaction	Negative Ions Rate Constant (cm^3/sec; cm^6/sec)	Product Ratio (%)	Energy (^oK, eV)
$F^- + CO_2 + He \rightarrow F^- \cdot CO_2 + He$	2.9×10^{-29}		296
$F^- + H \rightarrow e + FH$	1.6×10^{-9}		296
$F^- + NO_2 \rightarrow NO_2^- + F$	$\leq 6 \times 10^{-12}$		300
$H^- + CO \rightarrow e + CHO$	5×10^{-11}		278
$H^- + H \rightarrow e + H_2$	1.8×10^{-9}		296
$H^- + H_2O \rightarrow HO^- + H_2$	3.7×10^{-9}		297
$H^- + NO \rightarrow e + HNO$	4.6×10^{-10}		278
$H^- + NO_2 \rightarrow NO_2^- + H$	2.9×10^{-9}		300
$H^- + N_2O \rightarrow HO^- + N_2$	1.1×10^{-9}		278
$H^- + O_2 \rightarrow e + HO_2$	1.2×10^{-9}	≥ 99	278
$HO^- + CO_2 + Ar \rightarrow HO^- \cdot CO_2 + Ar$	8.6×10^{-28}		233
$HO^- + CO_2 + He \rightarrow HO^- \cdot CO_2 + He$	2.5×10^{-28}		296
$HO^- + CO_2 + O_2 \rightarrow HO^- \cdot CO_2 + O_2$	7.6×10^{-28}		296
$HO^- + H \rightarrow e + H_2O$	1.4×10^{-9}		296
$HO^- + H_2 \rightarrow H^- + H_2O$	$\leq 5 \times 10^{-12}$		300
$HO^- + H_2O + O_2 \rightarrow HO^- \cdot H_2O + O_2$	2.5×10^{-28}		296
$HO^- + N \rightarrow e + HNO$	$\leq 1 \times 10^{-11}$		300
$HO^- + NO_2 \rightarrow NO_2^- + HO$	1.1×10^{-9}		300
$HO^- + O \rightarrow e + HO_2$	2×10^{-10}		300
$HO^- + O_3 \rightarrow O_3^- + HO$	9×10^{-10}		300
$I^- + H \rightarrow e + HI$	$\leq 6 \times 10^{-11}$		296
$NO^- + CO \rightarrow e + CO + NO$	5.0×10^{-13}		193 - 506
$NO^- + CO_2 \rightarrow e + CO_2 + NO$	8.3×10^{-12}		193 - 506
$NO^- + ClH \rightarrow Cl^- + HNO$	1.6×10^{-9}		289
$NO^- + H_2 \rightarrow e + H_2 + NO$	2.3×10^{-13}		193 - 506
$NO^- + He \rightarrow e + He + NO$	2.4×10^{-13}		193 - 506

Tabular Data B-1.B-2. (Continued).

Reaction	Negative Ions Rate Constant (cm^3/sec; cm^6/sec)	Product Ratio (%)	Energy (^oK, eV)
$NO^- + NO \rightarrow e + 2NO$	5.0×10^{-12}		285 - 506
$NO^- + NO_2 \rightarrow NO_2^- + NO$	7.4×10^{-10}		285
$NO^- + N_2O \rightarrow e + NO + N_2O$	5.1×10^{-12}		193 - 506
$NO^- + Ne \rightarrow e + Ne + NO$	2.9×10^{-14}		285 - 506
$NO^- + O_2 \rightarrow O_2^- + NO$	5×10^{-10}		285
$NO_2^- + Cl_2 \rightarrow Cl_2^- + NO_2$	6.8×10^{-10}		280 - 500
$NO_2^- + H \rightarrow e + HNO_2$	3.7×10^{-10}		296
$NO_2^- + H_2O + O_2 \rightarrow NO_2^- \cdot H_2O + O_2$	1.6×10^{-28}		296
$NO_2^- + N \rightarrow$ products	$\leq 1 \times 10^{-11}$		300
$NO_2^- + NO_2 \rightarrow NO_3^- + NO$	$\leq 2 \times 10^{-13}$		298
$NO_2^- + N_2O \rightarrow NO_3^- + N_2$	$\leq 1 \times 10^{-12}$		298
$NO_2^- + O \rightarrow$ products	$\leq 1 \times 10^{-11}$		300
$NO_2^- + O_3 \rightarrow NO_3^- + O_2$	1.2×10^{-10}		300
$NO_2^- + CO_2 \rightarrow CO_3^- + NO$			300
$NO_3^- + CO_2 \rightarrow$ products	not observed		296
$NO_3^- + H \rightarrow$ products	$\leq 5 \times 10^{-11}$		296
$NO_3^- + N \rightarrow$ products	$\leq 1 \times 10^{-11}$		300
$NO_3^- + NO \rightarrow NO_2^- + NO_2$	$\leq 1 \times 10^{-12}$		300
$NO_3^- + O \rightarrow e + NO_2 + O_2$	$\leq 1 \times 10^{-11}$		300
$N_2O^- + O_2 \rightarrow O_3^- + N_2$	fast		80
$O^- + CO \rightarrow e + CO_2$	5.5×10^{-10}		0.05 - 2.7
$O^- + CO_2 \rightarrow e + CO_3$	$\leq 1 \times 10^{-13}$		300
$O^- + CO_2 + He \rightarrow CO_3^- + He$	1.5×10^{-28}		296
$O^- + CO_2 + O_2 \rightarrow CO_3^- + O_2$	3.1×10^{-28}		296
$O^- + ClH \rightarrow Cl^- + HO$	2.0×10^{-9}		300
$O^- + H_2 \rightarrow e + H_2O$	6.4×10^{-10}	94	0.04 - 0.5

Tabular Data B-1.B-2. (Continued).

Reaction	Negative Ions Rate Constant (cm^3/sec; cm^6/sec)	Product Ratio (%)	Energy (^oK, eV)
$O^- + H_2O \rightarrow e + H_2O_2$	$\leq 6 \times 10^{-13}$		296
$O^- + H_2O + O_2 \rightarrow O^- \cdot H_2O + O_2$	1.3×10^{-28}		296
$O^- + N \rightarrow e + NO$	2.2×10^{-10}		300
$O^- + NO \rightarrow e + NO_2$	2.1×10^{-10}		0.04 - 1.1
$O^- + NO_2 \rightarrow NO_2^- + O$	1.0×10^{-9}		300
$O^- + N_2 \rightarrow e + N_2O$	$\leq 1 \times 10^{-12}$		0.04 - 1
$O^- + N_2 + He \rightarrow NO_2^- + He$	4.0×10^{-31}		200
$O^- + N_2O \rightarrow NO^- + NO$	2.0×10^{-10}		0.04 - 1.6
$O^- + O \rightarrow e + O_2$	1.9×10^{-10}		300
$O^- + O_2 \rightarrow e + O_3$	$\leq 1 \times 10^{-12}$		300
$O^- + O_2(a\ ^1\Delta_g) \rightarrow e + O_3$	3×10^{-10}		300
$O^- + O_3 \rightarrow O_3^- + O$	8×10^{-10}		300
$O^- \cdot H_2O + H_2O \rightarrow HO^- \cdot H_2O + HO$	$\geq 1 \times 10^{-11}$		296
$O^- \cdot H_2O + O_2 \rightarrow O_3^- + H_2O$	$\geq 1 \times 10^{-11}$		296
$O_2^- + CO_2 + He \rightarrow CO_4^- + He$	4.7×10^{-29}		200
$O_2^- + CO_2 + O_2 \rightarrow CO_4^- + O_2$	4.7×10^{-29}		296
$O_2^- + ClH \rightarrow Cl^- + HO_2$	1.6×10^{-9}		289
$O_2^- + H \rightarrow e + HO_2$	1.4×10^{-9}		296
$O_2^- + H_2 \rightarrow$ products	$\leq 1 \times 10^{-12}$		300
$O_2^- + H_2O + O_2 \rightarrow O_2^- \cdot H_2O + O_2$	2.2×10^{-28}		296
$O_2^- + N \rightarrow e + NO_2$	4.0×10^{-10}		300
$O_2^- + NO_2 \rightarrow NO_2^- + O_2$	7×10^{-10}		300
$O_2^- + N_2 + He \rightarrow O_2^- \cdot N_2 + He$	4.0×10^{-32}		200
$O_2^- + N_2O \rightarrow NO_2^- + NO$	$\leq 2 \times 10^{-14}$		298
$O_2^- + O \rightarrow e + O_3$	3.0×10^{-10}	50	300
$O_2^- + O_2 + He \rightarrow O_4^- + He$	3.4×10^{-31}		200

Tabular Data B-1.B-2. (Continued).

Reaction	Negative Ions Rate Constant (cm^3/sec; cm^6/sec)	Product Ratio (%)	Energy (^oK, eV)
$O_2^- + O_2(a\ ^1\Delta_g) \rightarrow e + 2O_2$	2×10^{-10}		300
$O_2^- + O_3 \rightarrow O_3^- + O_2$	6×10^{-10}		300
$O_2^- \cdot H_2O + CO_2 \rightarrow CO_4^- + H_2O$	5.8×10^{-10}		300
$O_2^- \cdot H_2O + H \rightarrow e + HO_2 + H_2O$	8×10^{-10}		296
$O_2^- \cdot H_2O + H_2O + O_2 \rightarrow O_2^- \cdot 2H_2O + O_2$	6×10^{-28}		296
$O_2^- \cdot H_2O + NO \rightarrow NO_3^- + H_2O$	3.1×10^{-10}		300
$O_2^- \cdot H_2O + NO_2 \rightarrow NO_2^- + H_2O + O_2$	9×10^{-10}		296
$O_2^- \cdot 2H_2O + CO_2 \rightarrow CO_4^- \cdot H_2O + H_2O$			296
$O_2^- \cdot 2H_2O + H \rightarrow e + HO_2 + 2H_2O$	3×10^{-10}		296
$O_3^- + CO \rightarrow$ products	slow		300
$O_3^- + CO_2 \rightarrow CO_3^- + O_2$	5.5×10^{-10}		185 - 600
$O_3^- + Cl_2 \rightarrow Cl^- +$ product(s)	1.3×10^{-9}		280
$O_3^- + H \rightarrow HO^- + O_2$	8.4×10^{-10}		296
$O_3^- + H_2O + O_2 \rightarrow O_3^- \cdot H_2O + O_2$	2.7×10^{-28}		296
$O_3^- + NO \rightarrow$ products	2.6×10^{-12}		0.04 - 1.4
$O_3^- + NO_2 \rightarrow NO_3^- + O_2$	2.8×10^{-10}		280
$O_3^- + N_2 \rightarrow$ products	$\leq 1 \times 10^{-15}$		300
$O_3^- + N_2 + N_2 \rightarrow$ products	$\leq 1.5 \times 10^{-31}$		300
$O_3^- + N_2O \rightarrow e + N_2 + 2O_2$	$\leq 2 \times 10^{-14}$		298
$O_3^- + O \rightarrow O_2^- + O_2$	2.5×10^{-10}		300
$O_3^- \cdot H_2O + CO_2 \rightarrow CO_3^- + O_2 + H_2O$	3.5×10^{-10}		296
$O_3^- \cdot H_2O + H_2O + O_2 \rightarrow O_3^- \cdot 2H_2O + O_2$			296
$O_3^- \cdot 2H_2O + CO_2 \rightarrow CO_3^- \cdot H_2O + H_2O + O_2$	$\leq 1 \times 10^{-10}$		296
$O_4^- + CO \rightarrow CO_3^- + O_2$	$\leq 2.0 \times 10^{-11}$		300
$O_4^- + CO_2 \rightarrow CO_4^- + O_2$	4.3×10^{-10}		300
$O_4^- + H_2O \rightarrow O_2^- \cdot H_2O + O_2$	$\geq 1.0 \times 10^{-10}$		300

Tabular Data B-1.B-2. (Concluded).

Reaction	Negative Ions Rate Constant (cm^3/sec; cm^6/sec)	Product Ratio (%)	Energy (^oK, eV)
$O_4^- + NO \rightarrow NO_3^- + O_2$	2.5×10^{-10}		300
$O_4^- + N_2 \rightarrow O_2^- \cdot N_2 + O_2$	$\leq 1.0 \times 10^{-11}$		300
$O_4^- + N_2O \rightarrow O_2^- \cdot N_2O + O_2$	$\leq 1.0 \times 10^{-12}$		300
$O_4^- + O \rightarrow O_3^- + O_2$	4×10^{-10}		300
$S^- + CO \rightarrow e + COS$	3.1×10^{-10}		300
$S^- + H_2 \rightarrow e + H_2S$	$\leq 1 \times 10^{-15}$		300
$S^- + NO_2 \rightarrow NO_2^- + S$	1.3×10^{-9}		280
$S^- + O_2 \rightarrow e + O_2S$	3×10^{-11}		300

Section B-1.C. ENERGY TRANSFER; QUENCHING

CONTENTS

Page

INTRODUCTION

The actual form of a nuclear pumped laser is not yet known, and nuclear pumping may become important in a hybrid laser where the excitation and ionization produced by nuclear pumping might be used to supply electrons for an electrical discharge laser, an initiator for a pulsed chemical laser, or an initiator and sustainer for a cw chemical laser. An attempt to include, in detail, the data relevant to all these systems is beyond the scope of this work. However, it is practical to include examples of the kinetics packages currently being used in computer codes for these systems.

Chemical laser systems for HF, DF, and CO; transfer chemical laser systems for CO_2; e-beam sustained CO_2 systems; and several e-beam pumped excimer systems are included.

Tables B-1.C-1 through B-1.C-11 require some additional explanation. The rates cover the temperature and pressure ranges in the optical cavities of interest which are generally on the order of 200 to 1200°K and from 2 to 200 Torr. The rates are in the form

$$k = [A\ T^{-N} \exp\ (B/RT^{M})]\ \mathrm{cm}^3\ \mathrm{molecule}^{-1}\ \mathrm{sec}^{-1}$$

where B is in calories mole^{-1} and M = 1 if no entry appears. Abbreviated chain reaction models which give quite good results can be obtained from B-1.C-1 and B-1.C-7 by deleting reactions of excited $H_2(D_2)$, chain branching reactions, and V → R,T relaxation reactions of all species other than HF/DF and F and H atoms leaving 93 reactions for the F_2/H_2 chain reaction model and 146 reactions for the F_2/D_2 chain reaction model. An even more abbreviated model which is useful in treating systems in which precombustion is used to largely dissociate F_2 (or NF_x) with H_2/D_2; NH_x/ND_x or similar fuels is given in B-1.C-2 and B-1.C-8. Reaction subsets for use in the precombustor with cold reaction model are also given in B-1.C-6 and B-1.C-10. A reaction subset for use in pulsed systems where O_2 has been added to inhibit auto-ignition during mixing of the reactants is given in B-1.C-5, and a subset for use in the analysis of H_2-F_2 systems ignited chemically by NO, with or without added HI is given in B-1.C-4, while the transfer reaction subsets are given in B-1.C-3 and B-1.C-9.

Additional information on all the data included in this section may be obtained from the references.

Tabular Data B-1.C-1. Chain reaction F_2/H_2 model (148 reactions).

H2(1)	+F2		=HF(0)	+H	+F	1.4 -19			
H2(2)	+F2		=HF(0)	+H	+F	1.4 -19			
HF(4)	+F2		=HF(0)	+F	+F	4.0 -17			
HF(5)	+F2		=HF(0)	+F	+F	4.0 -17			
HF(6)	+F2		=HF(0)	+F	+F	4.0 -17			
F	+F	+M1	=F2	+M1		1.3 -32	1.0	1250.	
H	+H	+M2	=H2(2)	+M2		2.8 -30	1.0		
H	+F	+M4	=HF(6)	+M4		6.2 -30	1.0		
F	+H2(0)		=HF(1)	+H		4.3 -11		- 1600.	
F	+H2(1)		=HF(1)	+H		4.3 -11		- 1600.	
F	+H2(2)		=HF(1)	+H		4.3 -11		- 1600.	
F	+H2(0)		=HF(2)	+H		1.5 -10		- 1600.	
F	+H2(1)		=HF(2)	+H		1.5 -10		- 1600.	
F	+H2(2)		=HF(2)	+H		1.5 -10		- 1600.	
F	+H2(0)		=HF(3)	+H		7.3 -11		- 1600.	
F	+H2(1)		=HF(3)	+H		7.3 -11		- 1600.	
F	+H2(2)		=HF(3)	+H		7.3 -11		- 1600.	
HF(4)	+H		=F	+H2(0)		6.1 -12		- 500.	
HF(4)	+H		=F	+H2(1)		6.1 -12		- 500.	
HF(5)	+H		=F	+H2(0)		6.6 -12		- 510.	
HF(5)	+H		=F	+H2(1)		1.2 -11		- 510.	
HF(6)	+H		=F	+H2(0)		6.6 -12		- 560.	
HF(6)	+H		=F	+H2(1)		6.6 -12		- 560.	
HF(6)	+H		=F	+H2(2)		1.8 -11		- 560.	
H	+F2		=HF(0)	+F		1.9 -12		- 2400.	
H	+F2		=HF(1)	+F		4.15-12		- 2400.	
H	+F2		=HF(2)	+F		5.8 -12		- 2400.	
H	+F2		=HF(3)	+F		6.0 -12		- 2400.	
H	+F2		=HF(4)	+F		2.7 -11		- 2400.	
H	+F2		=HF(5)	+F		6.0 -11		- 2400.	
H	+F2		=HF(6)	+F		8.0 -11		- 2400.	
HF(1)	+M5		=HF(0)	+M5		2.0 -15	-0.5	53.	0.3333
HF(2)	+M5		=HF(1)	+M5		4.0 -15	-0.5	53.	0.3333
HF(3)	+M5		=HF(2)	+M5		6.0 -15	-0.5	53.	0.3333
HF(4)	+M5		=HF(3)	+M5		8.0 -15	-0.5	53.	0.3333
HF(5)	+M5		=HF(4)	+M5		1.0 -14	-0.5	53.	0.3333
HF(6)	+M5		=HF(5)	+M5		1.2 -14	-0.5	53.	0.3333
HF(2)	+M5		=HF(0)	+M5		2.0 -15	-0.5	53.	0.3333
HF(3)	+M5		=HF(1)	+M5		3.0 -15	-0.5	53.	0.3333
HF(4)	+M5		=HF(2)	+M5		4.0 -15	-0.5	53.	0.3333

Tabular Data B-1.C.1. Chain reaction F_2/H_2 model (148 reactions) (Continued).

		A	N	B	M
HF(5) +M5	=HF(3) +M5	5.0 -15	-0.5	53.	0.3333
HF(6) +M5	=HF(4) +M5	6.0 -15	-0.5	53.	0.3333
HF(3) +M5	=HF(0) +M5	2.0 -15	-0.5	53.	0.3333
HF(4) +M5	=HF(1) +M5	2.7 -15	-0.5	53.	0.3333
HF(5) +M5	=HF(2) +M5	3.3 -15	-0.5	53.	0.3333
HF(6) +M5	=HF(3) +M5	4.0 -15	-0.5	53.	0.3333
HF(4) +M5	=HF(0) +M5	2.0 -15	-0.5	53.	0.3333
HF(5) +M5	=HF(1) +M5	2.5 -15	-0.5	53.	0.3333
HF(6) +M5	=HF(2) +M5	3.0 -15	-0.5	53.	0.3333
HF(5) +M5	=HF(0) +M5	2.0 -15	-0.5	53.	0.3333
HF(6) +M5	=HF(1) +M5	2.4 -15	-0.5	53.	0.3333
HF(6) +M5	=HF(0) +M5	2.0 -15	-0.5	53.	0.3333
HF(1) +F	=HF(0) +F	5.0 - 9	0.75-	3600.	
HF(2) +F	=HF(1) +F	1.0 - 8	0.75-	3600.	
HF(2) +F	=HF(0) +F	5.0 - 9	0.75-	3600.	
HF(3) +F	=HF(2) +F	1.5 - 8	0.75-	3600.	
HF(3) +F	=HF(1) +F	7.5 - 9	0.75-	3600.	
HF(3) +F	=HF(0) +F	5.0 - 9	0.75-	3600.	
HF(4) +F	=HF(3) +F	2.0 - 8	0.75-	3600.	
HF(4) +F	=HF(2) +F	1.0 - 8	0.75-	3600.	
HF(4) +F	=HF(1) +F	6.3 - 9	0.75-	3600.	
HF(4) +F	=HF(0) +F	5.0 - 9	0.75-	3600.	
HF(5) +F	=HF(4) +F	2.5 - 8	0.75-	3600.	
HF(5) +F	=HF(3) +F	1.2 - 8	0.75-	3600.	
HF(5) +F	=HF(2) +F	8.3 - 9	0.75-	3600.	
HF(5) +F	=HF(1) +F	6.2 - 9	0.75-	3600.	
HF(5) +F	=HF(0) +F	5.0 - 9	0.75-	3600.	
HF(6) +F	=HF(5) +F	3.0 - 8	0.75-	3600.	
HF(6) +F	=HF(4) +F	1.5 - 8	0.75-	3600.	
HF(6) +F	=HF(3) +F	1.0 - 8	0.75-	3600.	
HF(6) +F	=HF(2) +F	7.5 - 9	0.75-	3600.	
HF(5) +F	=HF(1) +F	6.0 - 9	0.75-	3600.	
HF(6) +F	=HF(0) +F	5.0 - 9	0.75-	3600.	
HF(1) +M7	=HF(0) +M7	1.3 -27	-4.0		
HF(2) +M7	=HF(1) +M7	2.7 -27	-4.0		
HF(3) +M7	=HF(2) +M7	4.0 -27	-4.0		
HF(4) +M7	=HF(3) +M7	5.3 -27	-4.0		
HF(5) +M7	=HF(4) +M7	6.65-27	-4.0		
HF(6) +M7	=HF(5) +M7	8.0 -27	-4.0		
HF(1) +M8	=HF(0) +M8	1.4 -30	-5.0		

Tabular Data B-1.C-1. Chain reaction F_2/H_2 model (148 reactions) (Continued).

		A	N	B
HF(2) +M8	=HF(1) +M8	2.9 -30	-5.0	
HF(3) +M8	=HF(2) +M8	4.3 -30	-5.0	
HF(4) +M8	=HF(3) +M8	5.8 -30	-5.0	
HF(5) +M8	=HF(4) +M8	7.2 -30	-5.0	
HF(6) +M8	=HF(5) +M8	8.7 -30	-5.0	
HF(1) +M9	=HF(0) +M9	5.0 -20	-2.0	
HF(2) +M9	=HF(1) +M9	1.0 -19	-2.0	
HF(3) +M9	=HF(2) +M9	1.5 -19	-2.0	
HF(4) +M9	=HF(3) +M9	2.0 -19	-2.0	
HF(5) +M9	=HF(4) +M9	2.5 -19	-2.0	
HF(6) +M9	=HF(5) +M9	3.0 -19	-2.0	
HF(1) +M10	=HF(0) +M10	1.5 -10	0.28-	1170.
HF(2) +M10	=HF(0) +M10	7.1 -11	0.08-	900.
HF(2) +M10	=HF(1) +M10	7.3 -12	-0.20-	720.
HF(3) +M10	=HF(0) +M10	6.5 -11	0.06-	760.
HF(3) +M10	=HF(1) +M10	4.7 -11	0.08-	680.
HF(3) +M10	=HF(2) +M10	6.2 -11	0.09-	890.
HF(4) +M10	=HF(0) +M10	2.5 -10	0.32-	810.
HF(4) +M10	=HF(1) +M10	1.1 -11	-0.09-	640.
HF(4) +M10	=HF(2) +M10	2.1 -11	-0.03-	670.
HF(4) +M10	=HF(3) +M10	2.7 -11	-	520.
HF(5) +M10	=HF(0) +M10	1.6 -10	0.23-	640.
HF(5) +M10	=HF(1) +M10	6.6 -11	0.15-	610.
HF(5) +M10	=HF(2) +M10	3.3 -11	0.04-	710.
HF(5) +M10	=HF(3) +M10	5.3 -11	0.06-	670.
HF(5) +M10	=HF(4) +M10	3.6 -11	0.05-	530.
HF(6) +M10	=HF(0) +M10	1.3 -10	0.20-	620.
HF(6) +M10	=HF(1) +M10	6.6 -12	-0.16-	570.
HF(6) +M10	=HF(2) +M10	6.8 -11	0.15-	750.
HF(6) +M10	=HF(3) +M10	2.8 -11	0.01-	670.
HF(6) +M10	=HF(4) +M10	1.1 -10	0.21-	600.
HF(6) +M10	=HF(5) +M10	1.5 -10	0.22-	630.
HF(1) +M11	=HF(0) +M11	1.7 -19	-2.0	
HF(2) +M11	=HF(1) +M11	3.3 -19	-2.0	
HF(3) +M11	=HF(2) +M11	5.0 -19	-2.0	
HF(4) +M11	=HF(3) +M11	6.6 -19	-2.0	
HF(5) +M11	=HF(4) +M11	8.3 -19	-2.0	
HF(6) +M11	=HF(5) +M11	1.0 -18	-2.0	
HF(1) +HF(1)	=HF(0) +HF(2)	1.4 - 8	1.0	
HF(2) +HF(2)	=HF(1) +HF(3)	1.4 - 8	1.0	

Tabular Data B-1.C-1. Chain reaction F_2/H_2 model (148 reactions) (Continued).

		A	N
HF(3) +HF(3)	=HF(2) +HF(4)	1.4 - 8	1.0
HF(4) +HF(4)	=HF(3) +HF(5)	1.4 - 8	1.0
HF(5) +HF(5)	=HF(4) +HF(6)	1.4 - 8	1.0
HF(1) +HF(2)	=HF(0) +HF(3)	7.0 - 9	1.0
HF(2) +HF(3)	=HF(1) +HF(4)	7.0 - 9	1.0
HF(3) +HF(4)	=HF(2) +HF(5)	7.0 - 9	1.0
HF(4) +HF(5)	=HF(3) +HF(6)	7.0 - 9	1.0
HF(1) +HF(3)	=HF(0) +HF(4)	3.5 - 9	1.0
HF(2) +HF(4)	=HF(1) +HF(5)	3.5 - 9	1.0
HF(3) +HF(5)	=HF(2) +HF(6)	3.5 - 9	1.0
HF(1) +HF(4)	=HF(0) +HF(5)	1.7 - 9	1.0
HF(2) +HF(5)	=HF(1) +HF(6)	1.7 - 9	1.0
HF(0) +H2(1)	=HF(1) +H2(0)	1.5 -12	
HF(1) +H2(1)	=HF(2) +H2(0)	4.8 -12	
HF(2) +H2(1)	=HF(3) +H2(0)	1.5 -11	
HF(3) +H2(1)	=HF(4) +H2(0)	3.3 -11	
HF(4) +H2(1)	=HF(5) +H2(0)	6.9 -11	
HF(5) +H2(1)	=HF(6) +H2(0)	1.0 -10	
HF(0) +H2(2)	=HF(1) +H2(1)	1.5 -12	
HF(1) +H2(2)	=HF(2) +H2(1)	4.8 -12	
HF(2) +H2(2)	=HF(3) +H2(1)	1.5 -11	
HF(3) +H2(2)	=HF(4) +H2(1)	3.3 -11	
HF(4) +H2(2)	=HF(5) +H2(1)	6.9 -11	
HF(5) +H2(2)	=HF(6) +H2(1)	1.0 -10	
H2(1) +M12	=H2(0) +M12	4.2 -28	-4.3
H2(2) +M12	=H2(1) +M12	4.2 -28	-4.3
H2(1) +M13	=H2(0) +M13	1.7 -27	-4.3
H2(2) +M13	=H2(1) +M13	1.7 -27	-4.3

Tabular Data B-1.C-1. Chain reaction F_2/H_2 model (148 reactions) (Concluded).

<u>Catalytic Species</u>

M_1 = 2.4F, 2.4F_2; All others: 1.0

M_2 = 20H, All others: 1.0

M_4 = All species

M5 = HF, DF

M_7 = Ar, F_2

M_8 = He

M_9 = N_2

M_{10} = H

M_{11} = H_2

M_{12} = All species except H and H_2

M_{13} = 1000 H, H_2

Tabular Data B-1.C-2. Cold reaction F_2/H_2 model (64 reactions).

					A	N	B	M
F	+F	+M1	=F2	+M1	1.3 -32	1.0	1250.	
H	+H	+M2	=H2	+M2	2.8 -30	1.0		
H	+F	+M4	=HF(4)	+M4	6.2 -30	1.0		
F	+H2		=HF(1)	+H	4.3 -11		- 1600.	
F	+H2		=HF(2)	+H	1.5 -10		- 1600.	
F	+H2		=HF(3)	+H	7.3 -11		- 1600.	
HF(4)	+H		=F	+H2	6.1 -12		- 500.	
H	+F2		=HF(0)	+F	1.9 -12		- 2400.	
H	+F2		=HF(1)	+F	4.15-12		- 2400.	
H	+F2		=HF(2)	+F	5.8 -12		- 2400.	
H	+F2		=HF(3)	+F	6.0 -12		- 2400.	
H	+F2		=HF(4)	+F	1.7 -10		- 2400.	
HF(1)	+M5		=HF(0)	+M5	2.0 -15	-0.5	53.	0.3333
HF(2)	+M5		=HF(1)	+M5	4.0 -15	-0.5	53.	0.3333
HF(3)	+M5		=HF(2)	+M5	6.0 -15	-0.5	53.	0.3333
HF(4)	+M5		=HF(3)	+M5	8.0 -15	-0.5	53.	0.3333
HF(2)	+M5		=HF(0)	+M5	2.0 -15	-0.5	53.	0.3333
HF(3)	+M5		=HF(1)	+M5	3.0 -15	-0.5	53.	0.3333
HF(4)	+M5		=HF(2)	+M5	4.0 -15	-0.5	53.	0.3333
HF(3)	+M5		=HF(0)	+M5	2.0 -15	-0.5	53.	0.3333
HF(4)	+M5		=HF(1)	+M5	2.7 -15	-0.5	53.	0.3333
HF(4)	+M5		=HF(0)	+M5	2.0 -15	-0.5	53.	0.3333
HF(1)	+F		=HF(0)	+F	5.0 - 9	0.75	- 3600.	
HF(2)	+F		=HF(1)	+F	1.0 - 8	0.75	- 3600.	
HF(2)	+F		=HF(0)	+F	5.0 - 9	0.75	- 3600.	
HF(3)	+F		=HF(2)	+F	1.5 - 8	0.75	- 3600.	
HF(3)	+F		=HF(1)	+F	7.5 - 9	0.75	- 3600.	
HF(3)	+F		=HF(0)	+F	5.0 - 9	0.75	- 3600.	
HF(4)	+F		=HF(3)	+F	2.0 - 8	0.75	- 3600.	
HF(4)	+F		=HF(2)	+F	1.0 - 8	0.75	- 3600.	
HF(4)	+F		=HF(1)	+F	6.3 - 9	0.75	- 3600.	
HF(4)	+F		=HF(0)	+F	5.0 - 9	0.75	- 3600.	
HF(1)	+M7		=HF(0)	+M7	1.3 -27	-4.0		
HF(2)	+M7		=HF(1)	+M7	2.7 -27	-4.0		
HF(3)	+M7		=HF(2)	+M7	4.0 -27	-4.0		
HF(4)	+M7		=HF(3)	+M7	5.3 -27	-4.0		
HF(1)	+M8		=HF(0)	+M8	1.4 -30	-5.0		
HF(2)	+M8		=HF(1)	+M8	2.9 -30	-5.0		
HF(3)	+M8		=HF(2)	+M8	4.3 -30	-5.0		

Tabular Data B-1.C-2. Cold reaction F_2/H_2 model (64 reactions) (Continued).

		A N	B
HF(4) +M8	=HF(3) +M8	5.8 -30-5.0	
HF(1) +M9	=HF(0) +M9	5.0 -20-2.0	
HF(2) +M9	=HF(1) +M9	1.0 -19-2.0	
HF(3) +M9	=HF(2) +M9	1.5 -19-2.0	
HF(4) +M9	=HF(3) +M9	2.0 -19-2.0	
HF(1) +M10	=HF(0) +M10	1.5 -10 0.28-	1170.
HF(2) +M10	=HF(0) +M10	7.1 -11 0.08-	900.
HF(2) +M10	=HF(1) +M10	7.3 -12-0.20-	720.
HF(3) +M10	=HF(0) +M10	6.5 -11 0.06-	760.
HF(3) +M10	=HF(1) +M10	4.7 -11 0.08-	680.
HF(3) +M10	=HF(2) +M10	6.2 -11 0.09-	890.
HF(4) +M10	=HF(0) +M10	2.5 -10 0.32-	810.
HF(4) +M10	=HF(1) +M10	1.1 -11-0.09-	640.
HF(4) +M10	=HF(2) +M10	2.1 -11-0.03-	670.
HF(4) +M10	=HF(3) +M10	2.7 -11 -	520.
HF(1) +M11	=HF(0) +M11	1.7 -19-2.0	
HF(2) +M11	=HF(1) +M11	3.3 -19-2.0	
HF(3) +M11	=HF(2) +M11	5.0 -19-2.0	
HF(4) +M11	=HF(3) +M11	6.6 -19-2.0	
HF(1) +HF(1)	=HF(0) +HF(2)	1.4 - 8 1.0	
HF(2) +HF(2)	=HF(1) +HF(3)	1.4 - 8 1.0	
HF(3) +HF(3)	=HF(2) +HF(4)	1.4 - 8 1.0	
HF(1) +HF(2)	=HF(0) +HF(3)	7.0 - 9 1.0	
HF(2) +HF(3)	=HF(1) +HF(4)	7.0 - 9 1.0	
HF(1) +HF(3)	=HF(0) +HF(4)	3.5 - 9 1.0	

Tabular Data B-1.C-2. *Cold reaction* F_2/H_2 model (64 reactions) (Concluded).

Catalytic Species

M_1 = 2.4F, 2.4F_2; All others: 1.0

M_2 = 20H; All others: 1.0

M_4 = All species

M_5 = HF, DF

M_7 = Ar, F_2

M_8 = He

M_9 = N_2

M_{10} = H

M_{11} = H_2

Tabular Data B-1.C-3. HF/CO_2 transfer reaction model subset (35 reactions).

		A	N	B
HF(1) +CO2000	=HF(0) +CO2001	6.0 -11	0.7	
HF(2) +CO2000	=HF(1) +CO2001	2.4 -10	0.7	
HF(3) +CO2000	=HF(2) +CO2001	3.6 -10	0.7	
HF(4) +CO2000	=HF(3) +CO2001	7.2 -10	0.7	
HF(5) +CO2000	=HF(4) +CO2001	1.4 - 9	0.7	
HF(6) +CO2000	=HF(5) +CO2001	2.0 - 9	0.7	
CO2110+CO2000	=CO2100+CO2010	1.25-13	-0.5	
CO2030+CO2000	=CO2100+CO2010	1.8 -15	-0.5	
CO2030+CO2000	=CO2020+CO2010	3.1 -13	-0.5	
CO2100+CO2000	=CO2010+CO2010	4.0 -13		
CO2020+CO2000	=CO2010+CO2010	1.4 -12	-0.5	
CO2001+M5	=CO2110+M5	6.8 -11	0.7	
CO2001+M9	=CO2110+M9	1.1 -27	-4.8	1464.
CO2001+M14	=CO2110+M14	1.9 -31	-5.8	2436.
CO2001+M15	=CO2110+M15	2.2 -17	-1.5	
CO2001+M5	=CO2030+M5	3.4 -13		
CO2001+M9	=CO2030+M9	8.1 -31	-5.6	1464.
CO2001+M14	=CO2030+M14	1.4 -34	-6.6	2436.
CO2001+M15	=CO2030+M15	1.7 -20	-2.3	
CO2110+M16	=CO2030+M16	4.3 -17	-1.5	
CO2110+M16	=CO2020+M16	4.5 -27	-4.2	- 903.
CO2110+M16	=CO2020+M16	8.8 -20	-2.5	- 4410.
CO2110+M16	=CO2100+M16	8.6 -24	-3.8	- 549.
CO2030+M16	=CO2020+M16	9.3 -22	-3.3	- 1230.
CO2030+M16	=CO2100+M16	1.1 -21	-3.0	- 1060.
CO2100+M16	=CO2020+M16	7.9 -18	-1.5	
CO2100+M17	=CO2010+M17	5.65-22	-3.3	- 1460.
CO2100+M8	=CO2010+M8	1.8 -21	-3.0	843.
CO2100+M18	=CO2010+M18	4.3 -12		288.
CO2020+M17	=CO2010+M17	2.1 -21	-3.2	- 1350.
CO2020+M8	=CO2010+M8	3.8 -21	-3.0	843.
CO2020+M18	=CO2010+M18	9.1 -12		288.
CO2010+M17	=CO2000+M17	3.4 -26	-4.2	1130.
CO2010+M8	=CO2000+M8	9.9 -22	-3.0	843.
CO2010+M18	=CO2000+M18	2.4 -12		288.

Tabular Data B-1.C-3. HF/CO_2 transfer reaction model subset (35 reactions) (Concluded).

Catalytic Species

M_1 = 2.4F, $2.4F_2$; All others: 1.0

M_2 = 20H; All others: 1.0

M_4 = All species

M_5 = HF, DF

M_6 = F

M_7 = Ar, F_2

M_8 = He

M_9 = CO_2, N_2

M_{10} = H

M_{11} = H_2

M_{12} = All species except H and H_2

M_{13} = 1000H, H_2

M_{14} = Ar, $2F_2$, 45H, He, $2N_2$

M_{15} = H_2, 30F

M_{16} = 3H, $3H_2$, 1.5He; All others: 1.0

M_{17} = CO_2, HF, DF, 0.06 Ar, F, F_2, $0.5N_2$

M_{18} = H, H_2

Tabular Data B-1.C-4. $F_2/NO/HI/H_2$ reaction model subset (71 reactions).

						A	N	B
HF(1)	+M14		=HF(0)	+M14		6.0 -11	0.7	
HF(2)	+M14		=HF(1)	+M14		2.4 -10	0.7	
HF(3)	+M14		=HF(2)	+M14		3.6 -10	0.7	
HF(4)	+M14		=HF(3)	+M14		7.2 -10	0.7	
HF(5)	+M14		=HF(4)	+M14		1.4 - 9	0.7	
HF(6)	+M14		=HF(5)	+M14		2.0 - 9	0.7	
HF(1)	+NO(0)		=HF(0)	+NO(2)		5.0 -16	-1.0	
HF(2)	+NO(0)		=HF(1)	+NO(2)		1.0 -15	-1.0	
HF(3)	+NO(0)		=HF(2)	+NO(2)		1.5 -15	-1.0	
HF(4)	+NO(0)		=HF(3)	+NO(2)		2.0 -15	-1.0	
HF(5)	+NO(0)		=HF(4)	+NO(2)		2.5 -15	-1.0	
HF(6)	+NO(0)		=HF(5)	+NO(2)		3.0 -15	-1.0	
NO(0)	+F2		=FNO	+F		8.0 -14		- 1500.
F	+HI		=HF(1)	+I		1.8 -11		- 1000.
F	+HI		=HF(2)	+I		2.2 -11		- 1000.
F	+HI		=HF(3)	+I		2.6 -11		- 1000.
F	+HI		=HF(4)	+I		2.8 -11		- 1000.
F	+HI		=HF(5)	+I		3.3 -11		- 1000.
F	+HI		=HF(6)	+I		4.5 -11		- 1000.
F	+NO(0)	+M4	=FNO	+M4		2.5 -29	1.0	
H	+NO(0)	+M4	=HNO	+M4		1.5 -32		600.
I	+NO(0)	+M4	=INO	+M4		2.5 -29	1.0	
F	+I	+M4	=FI	+M4		7.0 -30	1.5	
H	+I	+M4	=HI	+M4		2.0 -29	1.5	
I	+I	+M15	=I2	+M15		4.2 -29	1.5	
H	+I2		=HI	+I		1.7 -11	-0.5	
H	+HI		=H2(0)	+I		1.2 -12	-0.5	
HI	+HI		=H2(0)	+I	+I	1.6 -12	-0.5	-43700.
F	+I2		=FI	+I		3.0 -13	-0.5	
I	+F2		=FI	+F		3.0 -13	-0.5	
FNO	+H		=HF(0)	+NO(0)		5.0 -13		- 2000.
FNO	+H		=HF(0)	+NO(1)		5.0 -13		- 2000.
FNO	+H		=HF(1)	+NO(0)		1.1 -12		- 2000.
FNO	+H		=HF(1)	+NO(1)		1.1 -12		- 2000.
FNO	+H		=HF(2)	+NO(0)		1.6 -12		- 2000.
FNO	+H		=HF(2)	+NO(1)		1.6 -12		- 2000.
FNO	+H		=HF(3)	+NO(0)		1.6 -12		- 2000.
FNO	+H		=HF(3)	+NO(1)		1.6 -12		- 2000.
FNO	+H		=HF(4)	+NO(0)		7.2 -12		- 2000.
FNO	+H		=HF(4)	+NO(1)		7.2 -12		- 2000.

Tabular Data B-1.C-4. $F_2/NO/HI/H_2$ reaction model subset (71 reactions) (Continued).

				A	N	B	M
FNO	+H	=HF(5)	+NO(0)	1.6 -11		- 2000.	
FNO	+H	=HF(5)	+NO(1)	1.6 -11		- 2000.	
FNO	+H	=HF(6)	+NO(0)	2.2 -11		- 2000.	
FNO	+H	=HF(6)	+NO(1)	2.2 -11		- 2000.	
FNO	+I	=FI	+NO(0)	1.0 -12		- 2000.	
HNO	+F	=HF(0)	+NO(0)	1.7 -13		- 2000.	
HNO	+F	=HF(0)	+NO(1)	1.7 -13		- 2000.	
HNO	+F	=HF(1)	+NO(0)	3.7 -13		- 2000.	
HNO	+F	=HF(1)	+NO(1)	3.7 -13		- 2000.	
HNO	+F	=HF(2)	+NO(0)	5.3 -13		- 2000.	
HNO	+F	=HF(2)	+NO(1)	5.3 -13		- 2000.	
HNO	+F	=HF(3)	+NO(0)	5.3 -13		- 2000.	
HNO	+F	=HF(3)	+NO(1)	5.3 -13		- 2000.	
HNO	+F	=HF(4)	+NO(0)	2.4 -12		- 2000.	
HNO	+F	=HF(4)	+NO(1)	2.4 -12		- 2000.	
HNO	+F	=HF(5)	+NO(0)	5.3 -12		- 2000.	
HNO	+F	=HF(5)	+NO(1)	5.3 -12		- 2000.	
HNO	+F	=HF(6)	+NO(0)	7.3 -12		- 2000.	
HNO	+F	=HF(6)	+NO(1)	7.3 -12		- 2000.	
HNO	+H	=H2(0)	+NO(0)	1.3 -11		- 2000.	
HNO	+I	=HI	+NO(0)	2.5 -11		- 2000.	
INO	+I	=I2	+NO(0)	1.0 -12		- 2000.	
INO	+F	=FI	+NO(0)	4.0 -12		- 2000.	
INO	+H	=HI	+NO(0)	1.0 -10		-2000.	
NO(1)	+NO(1)	=NO(2)	+NO(0)	1.4 - 8	1.0		
NO(1)	+NO(0)	=NO(0)	+NO(0)	2.0 -12	-0.5	- 80.	0.333
NO(2)	+NO(0)	=NO(1)	+NO(0)	4.0 -12	-0.5	- 80.	0.333
NO(1)	+M16	=NO(0)	+M16	4.0 -14	-0.5	- 80.	0.333
NO(2)	+M16	=NO(1)	+M16	8.0 -14	-0.5	- 80.	0.333
H2(1)	+NO(0)	=H2(0)	+NO(2)	5.0 -16	-1.0		
H2(2)	+NO(0)	=H2(1)	+NO(2)	1.0 -15	-1.0		

Tabular Data B-1.C-4. $F_2/NO/HI/H_2$ reaction model subset (71 reactions) (Concluded).

Catalytic Species

M_1 = 2.4F, $2.4F_2$; All others: 1.0

M_2 = 20 H; All others: 1.0

M_4 = All species

M_5 = HF, HI

M_6 = F, I

M_7 = Ar, F_2, FI, I_2

M_8 = He

M_9 = N_2

M_{10} = H

M_{11} = H_2

M_{12} = All species except H and H_2

M_{13} = 1000 H, H_2

M_{14} = FNO, HNO, INO

M_{15} = 5I, $5I_2$; All others: 1.0

M_{16} = All species except NO

Tabular Data B-1.C-5. $F_2/O_2/H_2$ reaction model subset (35 reactions).

						A	N	B
H	+O2	+M14	=HO2	+M14		6.7 -33		580.
O	+H	+M15	=OH	+M15		2.0 -32		
O	+O	+M15	=O2	+M15		3.8 -30	1.0	-340.
OH	+H	+M15	=H2O	+M15		6.1 -26	2.0	
OH	+H2(0)		=H2O	+H		1.0 -17	-2.0	-2900.
OH	+H		=H2(0)	+O		1.4 -14	-1.0	-7000.
OH	+O		=H	+O2		4.0 -11		
OH	+OH		=H2O	+O		1.0 -11		-1100.
OH	+F		=O	+HF(0)		3.0 -11		-5000.
H2O	+F		=HF(0)	+OH		3.0 -11		-5000.
HO2	+H		=H2(0)	+O2		4.2 -11		-700.
HO2	+H		=OH	+OH		4.2 -10		-1900.
HO2	+F		=HF(0)	+O2		1.0 -10		-2000.
HO2	+O		=OH	+O2		8.0 -11		-1000.
HO2	+OH		=H2O	+O2		8.3 -11		-1000.
HO2	+H2(0)		=H2O	+OH		1.2 -12		-18700.
HO2	+F2		=O2	+HF(0)	+F	2.0 -11		-12000.
HF(1)	+M16		=HF(0)	+M16		3.2 -02	3.0	
HF(2)	+M16		=HF(1)	+M16		6.4 -02	3.0	
HF(3)	+M16		=HF(2)	+M16		9.6 -02	3.0	
HF(4)	+M16		=HF(3)	+M16		12.8-02	3.0	
HF(5)	+M16		=HF(4)	+M16		16.0-02	3.0	
HF(6)	+M16		=HF(5)	+M16		19.2-02	3.0	
HF(1)	+H2O		=HF(0)	+H2O		2.3 -09	0.5	
HF(2)	+H2O		=HF(1)	+H2O		4.6 -09	0.5	
HF(3)	+H2O		=HF(2)	+H2O		6.9 -09	0.5	
HF(4)	+H2O		=HF(3)	+H2O		9.2 -09	0.5	
HF(5)	+H2O		=HF(4)	+H2O		11.5-09	0.5	
HF(6)	+H2O		=HF(5)	+H2O		13.8-09	0.5	
HF(1)	+O2		=HF(0)	+O2		2.0 -12	0.5	
HF(2)	+O2		=HF(1)	+O2		4.0 -12	0.5	
HF(3)	+O2		=HF(2)	+O2		6.0 -12	0.5	
HF(4)	+O2		=HF(3)	+O2		8.0 -12	0.5	
HF(5)	+O2		=HF(4)	+O2		10.0-12	0.5	
HF(6)	+O2		=HF(5)	+O2		12.0-12	0.5	

Tabular Data B-1.C-5. $F_2/O_2/H_2$ reaction model subset (35 reactions) (Concluded).

Catalytic Species

M_1 = 2.4F, $2.4F_2$, $2HO_2$. $2H_2O$; All others: 1.0

M_2 = 20H, $10H_2O$; All others: 1.0

M_4 = All species

M_5 = HF

M_7 = Ar, F_2

M_8 = He

M_9 = N_2

M_{10} = H

M_{11} = H_2

M_{12} = All species except H and H_2

M_{13} = 1000 H, H_2

M_{14} = HF, Ar, F, F_2, 2H, $2H_2$, He, $25HO_2$, $25H_2O$, $3N_2$, 3O, 2OH, $3O_2$

M_{15} = HF, 0.2 Ar, F, F_2, H, H_2, 0.2He, $3HO_2$, $3H_2O$, N_2, O, OH, O_2

M_{16} = O, OH, HO_2

Tabular Data B-1.C-6. $C\ell\ F_x/CS_2/H_2$ reaction model subset* (19 reactions).

					A	N	B
CL	+CL	+M4	=CL2	+M4	4.3 -31	1.0	1250.
CL	+F	+M4	=CLF	+M4	4.1 -32	1.0	1250.
H	+CL	+M4	=HCL	+M4	1.1 -31	1.0	
CL	+F2		=CLF	+F	9.1 -10	-	1400.0
CL	+H2		=HCL	+H	8.0 -11	-	5260.0
F	+CL2		=CLF	+CL	9.1 -10	-	1400.0
H	+CL2		=HCL	+CL	2.0 -10	-	2400.0
H	+CLF		=HCL	+F	1.0 -10	-	2400.0
H	+CLF		=HF(0)	+CL	1.0 -12	-	2400.0
H	+CLF		=HF(1)	+CL	2.1 -12	-	2400.0
H	+CLF		=HF(2)	+CL	2.9 -12	-	2400.0
H	+CLF		=HF(3)	+CL	3.0 -12	-	2400.0
H	+CLF		=HF(4)	+CL	1.4 -11	-	2400.0
H	+CLF		=HF(5)	+CL	3.0 -11	-	2400.0
H	+CLF		=HF(6)	+CL	4.0 -11	-	2400.0
F	+HCL		=HF(0)	+CL	3.3 -12	-	900.0
F	+HCL		=HF(1)	+CL	1.4 -11	-	900.0
F	+HCL		=HF(2)	+CL	2.1 -11	-	900.0
F	+HCL		=HF(3)	+CL	3.3 -12	-	900.0

Catalytic Species

M_1 = 2.4F, $2.4F_2$; All others: 1.0

M_2 = 20H, All others: 1.0

M_4 = All species

M_5 = HF, 0.2HCℓ

M_6 = F, Cℓ

*Note that M_6 replaces F in the HF(v) + F V-R, T relaxation reactions.

Tabular Data B-1.C-6. $C\ell F_x/CS_2/H_2$ reaction model subset* (19 reactions) (Concluded).

M_7 = Ar, F_2, $C\ell_2$, $C\ell F$, SF_4, SF_6, $4CF_4$

M_8 = He

M_9 = N_2

M_{10} = H

M_{11} = H_2, $0.5SOF_2$, $0.5SO_2F_2$

M_{12} = All species except H and H_2

M_{13} = 1000H, H_2

Tabular Data B-1.C-7. Chain reaction F_2/D_2 model (261 reactions).

						A	N	B
D2(1)	+F2		=DF(0)	+D	+F	1.0 -19		
D2(2)	+F2		=DF(0)	+D	+F	1.0 -19		
DF(5)	+F2		=DF(0)	+F	+F	4.0 -17		
DF(6)	+F2		=DF(0)	+F	+F	4.0 -17		
DF(7)	+F2		=DF(0)	+F	+F	4.0 -17		
DF(8)	+F2		=DF(0)	+F	+F	4.0 -17		
DF(9)	+F2		=DF(0)	+F	+F	4.0 -17		
F	+F	+M1	=F2	+M1		1.3 -32	1.0	1250.
D	+D	+M2	=D2(2)	+M2		2.8 -30	1.0	
D	+F	+M3	=DF(9)	+M3		6.2 -30	1.0	
F	+D2(0)		=DF(1)	+D		3.2 - 9	0.9	- 2000.
F	+D2(1)		=DF(1)	+D		3.2 - 9	0.9	- 2000.
F	+D2(2)		=DF(1)	+D		3.2 - 9	0.9	- 2000.
F	+D2(0)		=DF(2)	+D		7.6 - 9	0.9	- 2000.
F	+D2(1)		=DF(2)	+D		7.6 - 9	0.9	- 2000.
F	+D2(2)		=DF(2)	+D		7.6 - 9	0.9	- 2000.
F	+D2(0)		=DF(3)	+D		1.2 - 8	0.9	- 2000.
F	+D2(1)		=DF(3)	+D		1.2 - 8	0.9	- 2000.
F	+D2(2)		=DF(3)	+D		1.2 - 8	0.9	- 2000.
F	+D2(0)		=DF(4)	+D		9.0 - 9	0.9	- 2000.
F	+D2(1)		=DF(4)	+D		9.0 - 9	0.9	- 2000.
F	+D2(2)		=DF(4)	+D		9.0 - 9	0.9	- 2000.
D	+DF(5)		=F	+D2(0)		5.5 -12		- 500.
D	+DF(5)		=F	+D2(1)		5.5 -12		- 500.
D	+DF(5)		=F	+D2(2)		5.5 -12		- 500.
D	+DF(6)		=F	+D2(0)		5.5 -12		- 500.
D	+DF(6)		=F	+D2(1)		5.5 -12		- 500.
D	+DF(6)		=F	+D2(2)		5.5 -12		- 500.
D	+DF(7)		=F	+D2(0)		5.5 -12		- 500.
D	+DF(7)		=F	+D2(1)		5.5 -12		- 500.
D	+DF(7)		=F	+D2(2)		5.5 -12		- 500.
D	+DF(8)		=F	+D2(0)		5.5 -12		- 500.
D	+DF(8)		=F	+D2(1)		5.5 -12		- 500.
D	+DF(8)		=F	+D2(2)		5.5 -12		- 500.
D	+DF(9)		=F	+D2(0)		5.5 -12		- 500.
D	+DF(9)		=F	+D2(1)		5.5 -12		- 500.
D	+DF(9)		=F	+D2(2)		5.5 -12		- 500.
D	+F2		=DF(4)	+F		2.7 -12		- 2400.
D	+F2		=DF(5)	+F		4.7 -12		- 2400.
D	+F2		=DF(6)	+F		9.1 -12		- 2400.

Tabular Data B-1.C-7. Chain reaction F_2/D_2 model (261 reactions) (Continued).

				A	N	B
D	+F2	=DF(7)	+F	1.6 -11		- 2400.
D	+F2	=DF(8)	+F	2.5 -11		- 2400.
D	+F2	=DF(9)	+F	7.3 -12		- 2400.
DF(1)	+M4	=DF(0)	+M4	2.0 -22	-2.9	3200.
DF(2)	+M4	=DF(1)	+M4	4.0 -22	-2.9	3200.
DF(2)	+M4	=DF(0)	+M4	2.0 -22	-2.9	3200.
DF(3)	+M4	=DF(2)	+M4	6.0 -22	-2.9	3200.
DF(3)	+M4	=DF(1)	+M4	3.0 -22	-2.9	3200.
DF(3)	+M4	=DF(0)	+M4	2.0 -22	-2.9	3200.
DF(4)	+M4	=DF(3)	+M4	8.0 -22	-2.9	3200.
DF(4)	+M4	=DF(2)	+M4	4.0 -22	-2.9	3200.
DF(4)	+M4	=DF(1)	+M4	2.7 -22	-2.9	3200.
DF(4)	+M4	=DF(0)	+M4	2.0 -22	-2.9	3200.
DF(5)	+M4	=DF(4)	+M4	1.0 -21	-2.9	3200.
DF(5)	+M4	=DF(3)	+M4	5.0 -22	-2.9	3200.
DF(5)	+M4	=DF(2)	+M4	3.3 -22	-2.9	3200.
DF(5)	+M4	=DF(1)	+M4	2.5 -22	-2.9	3200.
DF(5)	+M4	=DF(0)	+M4	2.0 -22	-2.9	3200.
DF(6)	+M4	=DF(5)	+M4	1.2 -21	-2.9	3200.
DF(6)	+M4	=DF(4)	+M4	6.0 -22	-2.9	3200.
DF(6)	+M4	=DF(3)	+M4	4.0 -22	-2.9	3200.
DF(6)	+M4	=DF(2)	+M4	3.0 -22	-2.9	3200.
DF(6)	+M4	=DF(1)	+M4	2.4 -22	-2.9	3200.
DF(6)	+M4	=DF(0)	+M4	2.0 -22	-2.9	3200.
DF(7)	+M4	=DF(6)	+M4	1.4 -21	-2.9	3200.
DF(7)	+M4	=DF(5)	+M4	7.0 -22	-2.9	3200.
DF(7)	+M4	=DF(4)	+M4	4.7 -22	-2.9	3200.
DF(7)	+M4	=DF(3)	+M4	3.5 -22	-2.9	3200.
DF(7)	+M4	=DF(2)	+M4	2.8 -22	-2.9	3200.
DF(7)	+M4	=DF(1)	+M4	2.3 -22	-2.9	3200.
DF(7)	+M4	=DF(0)	+M4	2.0 -22	-2.9	3200.
DF(8)	+M4	=DF(7)	+M4	1.6 -21	-2.9	3200.
DF(8)	+M4	=DF(6)	+M4	8.0 -22	-2.9	3200.
DF(8)	+M4	=DF(5)	+M4	5.3 -22	-2.9	3200.
DF(8)	+M4	=DF(4)	+M4	4.0 -22	-2.9	3200.
DF(8)	+M4	=DF(3)	+M4	3.2 -22	-2.9	3200.
DF(8)	+M4	=DF(2)	+M4	2.7 -22	-2.9	3200.
DF(8)	+M4	=DF(1)	+M4	2.3 -22	-2.9	3200.
DF(8)	+M4	=DF(0)	+M4	2.0 -22	-2.9	3200.
DF(9)	+M4	=DF(8)	+M4	1.8 -21	-2.9	3200.

Tabular Data B-1.C-7. Chain reaction F_2/D_2 model (261 reactions) (Continued).

		A	N	B
DF(9) +M4	=DF(7) +M4	9.0 -22	-2.9	3200.
DF(9) +M4	=DF(6) +M4	6.0 -22	-2.9	3200.
DF(9) +M4	=DF(5) +M4	4.5 -22	-2.9	3200.
DF(9) +M4	=DF(4) +M4	3.6 -22	-2.9	3200.
DF(9) +M4	=DF(3) +M4	3.0 -22	-2.9	3200.
DF(9) +M4	=DF(2) +M4	2.7 -22	-2.9	3200.
DF(9) +M4	=DF(1) +M4	2.2 -22	-2.9	3200.
DF(9) +M4	=DF(0) +M4	2.0 -22	-2.9	3200.
DF(1) +M5	=DF(0) +M5	3.8 -21	-2.2	
DF(2) +M5	=DF(1) +M5	7.6 -21	-2.2	
DF(3) +M5	=DF(2) +M5	1.1 -20	-2.2	
DF(4) +M5	=DF(3) +M5	1.5 -20	-2.2	
DF(5) +M5	=DF(4) +M5	1.9 -20	-2.2	
DF(6) +M5	=DF(5) +M5	2.3 -20	-2.2	
DF(7) +M5	=DF(6) +M5	2.7 -20	-2.2	
DF(8) +M5	=DF(7) +M5	3.1 -20	-2.2	
DF(9) +M5	=DF(8) +M5	3.4 -20	-2.2	
DF(1) +M6	=DF(0) +M6	9.3 -23	-3.0	
DF(2) +M6	=DF(1) +M6	1.9 -22	-3.0	
DF(3) +M6	=DF(2) +M6	2.8 -22	-3.0	
DF(4) +M6	=DF(3) +M6	3.7 -22	-3.0	
DF(5) +M6	=DF(4) +M6	4.6 -22	-3.0	
DF(6) +M6	=DF(5) +M6	5.6 -22	-3.0	
DF(7) +M6	=DF(6) +M6	6.5 -22	-3.0	
DF(8) +M6	=DF(7) +M6	7.4 -22	-3.0	
DF(9) +M6	=DF(8) +M6	8.4 -22	-3.0	
DF(1) +D	=DF(0) +D	2.7 - 9	0.75-	2180.
DF(2) +D	=DF(0) +D	3.6 - 9	0.73-	2220.
DF(2) +D	=DF(1) +D	4.1 -10	0.51-	2080.
DF(3) +D	=DF(0) +D	2.4 - 9	0.70-	2240.
DF(3) +D	=DF(1) +D	3.7 - 9	0.80-	2160.
DF(3) +D	=DF(2) +D	3.3 - 9	0.76-	2170.
DF(4) +D	=DF(0) +D	2.9 - 9	0.72-	2200.
DF(4) +D	=DF(1) +D	2.9 - 9	0.72-	2200.
DF(4) +D	=DF(2) +D	2.9 - 9	0.72-	2200.
DF(4) +D	=DF(3) +D	2.9 - 9	0.72-	2200.
DF(5) +D	=DF(0) +D	2.8 - 9	0.72-	2210.
DF(5) +D	=DF(1) +D	2.8 - 9	0.72-	2210.
DF(5) +D	=DF(2) +D	2.8 - 9	0.72-	2210.
DF(5) +D	=DF(3) +D	2.8 - 9	0.72-	2210.

Tabular Data B-1.C-7. Chain reaction F_2/D_2 model (261 reactions) (Continued).

		A	N	B
DF(5) +D	=DF(4) +D	2.8 - 9	0.72-	2210.
DF(6) +D	=DF(0) +D	2.7 - 9	0.77-	2190.
DF(6) +D	=DF(1) +D	1.1 - 9	0.64-	2240.
DF(6) +D	=DF(2) +D	1.5 - 9	0.66-	2270.
DF(6) +D	=DF(3) +D	2.8 - 9	0.71-	2230.
DF(6) +D	=DF(4) +D	2.2 - 9	0.75-	2250.
DF(6) +D	=DF(5) +D	5.6 - 9	0.78-	2200.
DF(7) +D	=DF(0) +D	2.9 - 9	0.71-	2230.
DF(7) +D	=DF(1) +D	2.9 - 9	0.71-	2230.
DF(7) +D	=DF(2) +D	2.9 - 9	0.71-	2230.
DF(7) +D	=DF(3) +D	2.9 - 9	0.71-	2230.
DF(7) +D	=DF(4) +D	2.9 - 9	0.71-	2230.
DF(7) +D	=DF(5) +D	2.9 - 9	0.71-	2230.
DF(7) +D	=DF(6) +D	2.9 - 9	0.71-	2230.
DF(8) +D	=DF(0) +D	3.3 - 9	0.71-	2240.
DF(8) +D	=DF(1) +D	3.3 - 9	0.71-	2240.
DF(8) +D	=DF(2) +D	3.3 - 9	0.71-	2240.
DF(8) +D	=DF(3) +D	3.3 - 9	0.71-	2240.
DF(8) +D	=DF(4) +D	3.3 - 9	0.71-	2240.
DF(8) +D	=DF(5) +D	3.3 - 9	0.71-	2240.
DF(8) +D	=DF(6) +D	3.3 - 9	0.71-	2240.
DF(8) +D	=DF(7) +D	3.3 - 9	0.71-	2240.
DF(9) +D	=DF(0) +D	3.7 - 9	0.7 -	2250.
DF(9) +D	=DF(1) +D	3.7 - 9	0.7 -	2250.
DF(9) +D	=DF(2) +D	3.7 - 9	0.7 -	2250.
DF(9) +D	=DF(3) +D	3.7 - 9	0.7 -	2250.
DF(9) +D	=DF(4) +D	3.7 - 9	0.7 -	2250.
DF(9) +D	=DF(5) +D	3.7 - 9	0.7 -	2250.
DF(9) +D	=DF(6) +D	3.7 - 9	0.7 -	2250.
DF(9) +D	=DF(7) +D	3.7 - 9	0.7 -	2250.
DF(9) +D	=DF(8) +D	3.7 - 9	0.7 -	2250.
DF(1) +M7	=DF(0) +M7	4.5 -30	-4.7	
DF(2) +M7	=DF(1) +M7	9.0 -30	-4.7	
DF(3) +M7	=DF(2) +M7	1.4 -29	-4.7	
DF(4) +M7	=DF(3) +M7	1.8 -29	-4.7	
DF(5) +M7	=DF(4) +M7	2.2 -29	-4.7	
DF(6) +M7	=DF(5) +M7	2.7 -29	-4.7	
DF(7) +M7	=DF(6) +M7	3.1 -29	-4.7	
DF(8) +M7	=DF(7) +M7	3.6 -29	-4.7	
DF(9) +M7	=DF(8) +M7	4.0 -29	-4.7	

Tabular Data B-1.C-7. Chain reaction F_2/D_2 model (261 reactions) (Continued).

		A		N		B
DF(1) +F	=DF(0) +F	2.5	-	9	0.75-	3600.
DF(2) +F	=DF(1) +F	5.0	-	9	0.75-	3600.
DF(2) +F	=DF(0) +F	2.5	-	9	0.75-	3600.
DF(3) +F	=DF(2) +F	7.5	-	9	0.75-	3600.
DF(3) +F	=DF(1) +F	3.7	-	9	0.75-	3600.
DF(3) +F	=DF(0) +F	2.5	-	9	0.75-	3600.
DF(4) +F	=DF(3) +F	1.0	-	8	0.75-	3600.
DF(4) +F	=DF(2) +F	5.0	-	9	0.75-	3600.
DF(4) +F	=DF(1) +F	3.3	-	9	0.75-	3600.
DF(4) +F	=DF(0) +F	2.5	-	9	0.75-	3600.
DF(5) +F	=DF(4) +F	1.2	-	8	0.75-	3600.
DF(5) +F	=DF(3) +F	6.2	-	9	0.75-	3600.
DF(5) +F	=DF(2) +F	4.2	-	9	0.75-	3600.
DF(5) +F	=DF(1) +F	3.0	-	9	0.75-	3600.
DF(5) +F	=DF(0) +F	2.5	-	9	0.75-	3600.
DF(6) +F	=DF(5) +F	1.5	-	8	0.75-	3600.
DF(6) +F	=DF(4) +F	7.5	-	9	0.75-	3600.
DF(6) +F	=DF(3) +F	5.0	-	9	0.75-	3600.
DF(6) +F	=DF(2) +F	3.8	-	9	0.75-	3600.
DF(6) +F	=DF(1) +F	3.0	-	9	0.75-	3600.
DF(6) +F	=DF(0) +F	2.5	-	9	0.75-	3600.
DF(7) +F	=DF(6) +F	1.8	-	8	0.75-	3600.
DF(7) +F	=DF(5) +F	8.7	-	9	0.75-	3600.
DF(7) +F	=DF(4) +F	5.8	-	9	0.75-	3600.
DF(7) +F	=DF(3) +F	4.4	-	9	0.75-	3600.
DF(7) +F	=DF(2) +F	3.5	-	9	0.75-	3600.
DF(7) +F	=DF(1) +F	2.9	-	9	0.75-	3600.
DF(7) +F	=DF(0) +F	2.5	-	9	0.75-	3600.
DF(8) +F	=DF(7) +F	2.0	-	8	0.75-	3600.
DF(8) +F	=DF(6) +F	1.0	-	8	0.75-	3600.
DF(8) +F	=DF(5) +F	6.7	-	9	0.75-	3600.
DF(8) +F	=DF(4) +F	5.0	-	9	0.75-	3600.
DF(8) +F	=DF(3) +F	4.0	-	9	0.75-	3600.
DF(8) +F	=DF(2) +F	3.3	-	9	0.75-	3600.
DF(8) +F	=DF(1) +F	2.8	-	9	0.75-	3600.
DF(8) +F	=DF(0) +F	2.5	-	9	0.75-	3600.
DF(9) +F	=DF(8) +F	2.3	-	8	0.75-	3600.
DF(9) +F	=DF(7) +F	1.1	-	8	0.75-	3600.
DF(9) +F	=DF(6) +F	7.5	-	9	0.75-	3600.
DF(9) +F	=DF(5) +F	5.6	-	9	0.75-	3600.

Tabular Data B-1.C-7. Chain reaction F_2/D_2 model (261 reactions) (Continued).

		A	N	B
DF(9) +F	=DF(4) +F	4.5 - 9	0.75-	3600.
DF(9) +F	=DF(3) +F	3.8 - 9	0.75-	3600.
DF(9) +F	=DF(2) +F	3.2 - 9	0.75-	3600.
DF(9) +F	=DF(1) +F	2.8 - 9	0.75-	3600.
DF(9) +F	=DF(0) +F	2.5 - 9	0.75-	3600.
DF(1) +DF(1)	=DF(0) +DF(2)	1.0 - 8	1.0	
DF(2) +DF(2)	=DF(1) +DF(3)	1.0 - 8	1.0	
DF(3) +DF(3)	=DF(2) +DF(4)	1.0 - 8	1.0	
DF(4) +DF(4)	=DF(3) +DF(5)	1.0 - 8	1.0	
DF(5) +DF(5)	=DF(4) +DF(6)	1.0 - 8	1.0	
DF(6) +DF(6)	=DF(5) +DF(7)	1.0 - 8	1.0	
DF(7) +DF(7)	=DF(6) +DF(8)	1.0 - 8	1.0	
DF(8) +DF(8)	=DF(7) +DF(9)	1.0 - 8	1.0	
DF(1) +DF(2)	=DF(0) +DF(3)	5.0 - 9	1.0	
DF(2) +DF(3)	=DF(1) +DF(4)	5.0 - 9	1.0	
DF(3) +DF(4)	=DF(2) +DF(5)	5.0 - 9	1.0	
DF(4) +DF(5)	=DF(3) +DF(6)	5.0 - 9	1.0	
DF(5) +DF(6)	=DF(4) +DF(7)	5.0 - 9	1.0	
DF(6) +DF(7)	=DF(5) +DF(8)	5.0 - 9	1.0	
DF(7) +DF(8)	=DF(6) +DF(9)	5.0 - 9	1.0	
DF(1) +DF(3)	=DF(0) +DF(4)	2.5 - 9	1.0	
DF(2) +DF(4)	=DF(1) +DF(5)	2.5 - 9	1.0	
DF(3) +DF(5)	=DF(2) +DF(6)	2.5 - 9	1.0	
DF(4) +DF(6)	=DF(3) +DF(7)	2.5 - 9	1.0	
DF(5) +DF(7)	=DF(4) +DF(8)	2.5 - 9	1.0	
DF(6) +DF(8)	=DF(5) +DF(9)	2.5 - 9	1.0	
DF(1) +DF(4)	=DF(0) +DF(5)	1.2 - 9	1.0	
DF(2) +DF(5)	=DF(1) +DF(6)	1.2 - 9	1.0	
DF(3) +DF(6)	=DF(2) +DF(7)	1.2 - 9	1.0	
DF(4) +DF(7)	=DF(3) +DF(8)	1.2 - 9	1.0	
DF(5) +DF(8)	=DF(4) +DF(9)	1.2 - 9	1.0	
DF(1) +D2(0)	=DF(0) +D2(1)	5.0 -14	-0.5	
DF(2) +D2(0)	=DF(1) +D2(1)	1.0 -13	-0.5	
DF(2) +D2(0)	=DF(0) +D2(2)	1.0 -13	-0.5	
DF(3) +D2(0)	=DF(2) +D2(1)	1.5 -13	-0.5	
DF(3) +D2(0)	=DF(1) +D2(2)	1.5 -13	-0.5	
DF(4) +D2(0)	=DF(3) +D2(1)	2.0 -13	-0.5	
DF(4) +D2(0)	=DF(2) +D2(2)	2.0 -13	-0.5	
DF(5) +D2(0)	=DF(4) +D2(1)	2.5 -13	-0.5	
DF(5) +D2(0)	=DF(3) +D2(2)	2.5 -13	-0.5	

Tabular Data B-1.C-7. Chain reaction F_2/D_2 model (261 reactions) (Concluded).

				A	N
DF(6)	+D2(0)	=DF(5)	+D2(1)	3.0	-13-0.5
DF(6)	+D2(0)	=DF(4)	+D2(2)	3.0	-13-0.5
DF(7)	+D2(0)	=DF(6)	+D2(1)	3.5	-13-0.5
DF(7)	+D2(0)	=DF(5)	+D2(2)	3.5	-13-0.5
DF(8)	+D2(0)	=DF(7)	+D2(1)	4.0	-13-0.5
DF(8)	+D2(0)	=DF(6)	+D2(2)	4.0	-13-0.5
DF(9)	+D2(0)	=DF(8)	+D2(1)	4.5	-13-0.5
DF(9)	+D2(0)	=DF(7)	+D2(2)	4.5	-13-0.5
DF(1)	+D2(1)	=DF(0)	+D2(2)	5.0	-14-0.5
DF(2)	+D2(1)	=DF(1)	+D2(2)	1.0	-13-0.5
DF(3)	+D2(1)	=DF(2)	+D2(2)	1.5	-13-0.5
DF(4)	+D2(1)	=DF(3)	+D2(2)	2.0	-13-0.5
DF(5)	+D2(1)	=DF(4)	+D2(2)	2.5	-13-0.5
DF(6)	+D2(1)	=DF(5)	+D2(2)	3.0	-13-0.5
DF(7)	+D2(1)	=DF(6)	+D2(2)	3.5	-13-0.5
DF(8)	+D2(1)	=DF(7)	+D2(2)	4.0	-13-0.5
DF(9)	+D2(1)	=DF(8)	+D2(2)	4.5	-13-0.5
D2(1)	+M15	=D2(0)	+M15	1.5	-27-4.3
D2(2)	+M15	=D2(1)	+M15	1.5	-27-4.3
D2(1)	+M16	=D2(0)	+M16	3.0	-28-4.3
D2(2)	+M16	=D2(1)	+M16	3.0	-28-4.3

Catalytic Species

M_1 = 2.4F, $2.4F_2$; All others: 1.0

M_2 = 20D, $1.75D_2$; All others: 1.0

M_3 = All species

M_4 = DF, 2HF

M_5 = N_2

M_6 = D_2

M_7 = Ar, 2He, F_2

M_{15} = 1000D, D_2

M_{16} = DF, HF, Ar, F, F_2, He, N_2

Tabular Data D-1.C-8. Cold reaction F_2/D_2 model (127 reactions).

					A	N	B
F	+F	+M1	=F2	+M1	1.3 -32	1.0	1250.
D	+D	+M2	=D2	+M2	2.8 -30	1.0	
D	+F	+M3	=DF(5)	+M3	6.2 -30	1.0	
F	+D2		=DF(1)	+D	3.2 - 9	0.9	- 2000.
F	+D2		=DF(2)	+D	7.6 - 9	0.9	- 2000.
F	+D2		=DF(3)	+D	1.2 - 8	0.9	- 2000.
F	+D2		=DF(4)	+D	9.0 - 9	0.9	- 2000.
D	+DF(5)		=F	+D2	5.5 -12		- 500.
D	+F2		=DF(4)	+F	2.7 -12		- 2400.
D	+F2		=DF(5)	+F	6.2 -11		- 2400.
DF(1)	+M4		=DF(0)	+M4	2.0 -22	-2.9	3200.
DF(2)	+M4		=DF(1)	+M4	4.0 -22	-2.9	3200.
DF(2)	+M4		=DF(0)	+M4	2.0 -22	-2.9	3200.
DF(3)	+M4		=DF(2)	+M4	6.0 -22	-2.9	3200.
DF(3)	+M4		=DF(1)	+M4	3.0 -22	-2.9	3200.
DF(3)	+M4		=DF(0)	+M4	2.0 -22	-2.9	3200.
DF(4)	+M4		=DF(3)	+M4	8.0 -22	-2.9	3200.
DF(4)	+M4		=DF(2)	+M4	4.0 -22	-2.9	3200.
DF(4)	+M4		=DF(1)	+M4	2.7 -22	-2.9	3200.
DF(4)	+M4		=DF(0)	+M4	2.0 -22	-2.9	3200.
DF(5)	+M4		=DF(4)	+M4	1.0 -21	-2.9	3200.
DF(5)	+M4		=DF(3)	+M4	5.0 -22	-2.9	3200.
DF(5)	+M4		=DF(2)	+M4	3.3 -22	-2.9	3200.
DF(5)	+M4		=DF(1)	+M4	2.5 -22	-2.9	3200.
DF(5)	+M4		=DF(0)	+M4	2.0 -22	-2.9	3200.
DF(1)	+M5		=DF(0)	+M5	3.8 -21	-2.2	
DF(2)	+M5		=DF(1)	+M5	7.6 -21	-2.2	
DF(3)	+M5		=DF(2)	+M5	1.1 -20	-2.2	
DF(4)	+M5		=DF(3)	+M5	1.5 -20	-2.2	
DF(5)	+M5		=DF(4)	+M5	1.9 -20	-2.2	
DF(1)	+M6		=DF(0)	+M6	9.3 -23	-3.0	
DF(2)	+M6		=DF(1)	+M6	1.9 -22	-3.0	
DF(3)	+M6		=DF(2)	+M6	2.8 -22	-3.0	
DF(4)	+M6		=DF(3)	+M6	3.7 -22	-3.0	
DF(5)	+M6		=DF(4)	+M6	4.6 -22	-3.0	
DF(1)	+M7		=DF(0)	+M7	4.5 -30	-4.7	
DF(2)	+M7		=DF(1)	+M7	9.0 -30	-4.7	
DF(3)	+M7		=DF(2)	+M7	1.4 -29	-4.7	
DF(4)	+M7		=DF(3)	+M7	1.8 -29	-4.7	
DF(5)	+M7		=DF(4)	+M7	2.2 -29	-4.7	

Tabular Data B-1.C-8. Cold reaction F_2/D_2 model (127 reactions) (Concluded).

		A	N	B
DF(1) +D	=DF(0) +D	2.7 - 9	0.75-	2180.
DF(2) +D	=DF(0) +D	3.6 - 9	0.73-	2220.
DF(2) +D	=DF(1) +D	4.1 -10	0.51-	2080.
DF(3) +D	=DF(0) +D	2.4 - 9	0.70-	2240.
DF(3) +D	=DF(1) +D	3.7 - 9	0.80-	2160.
DF(3) +D	=DF(2) +D	3.3 - 9	0.76-	2170.
DF(4) +D	=DF(0) +D	2.9 - 9	0.72-	2200.
DF(4) +D	=DF(1) +D	2.9 - 9	0.72-	2200.
DF(4) +D	=DF(2) +D	2.9 - 9	0.72-	2200.
DF(4) +D	=DF(3) +D	2.9 - 9	0.72-	2200.
DF(5) +D	=DF(0) +D	2.8 - 9	0.72-	2210.
DF(5) +D	=DF(1) +D	2.8 - 9	0.72-	2210.
DF(5) +D	=DF(2) +D	2.8 - 9	0.72-	2210.
DF(5) +D	=DF(3) +D	2.8 - 9	0.72-	2210.
DF(5) +D	=DF(4) +D	2.8 - 9	0.72-	2210.
DF(1) +F	=DF(0) +F	2.5 - 9	0.75-	3600.
DF(2) +F	=DF(1) +F	5.0 - 9	0.75-	3600.
DF(2) +F	=DF(0) +F	2.5 - 9	0.75-	3600.
DF(3) +F	=DF(2) +F	7.5 - 9	0.75-	3600.
DF(3) +F	=DF(1) +F	3.7 - 9	0.75-	3600.
DF(3) +F	=DF(0) +F	2.5 - 9	0.75-	3600.
DF(4) +F	=DF(3) +F	1.0 - 8	0.75-	3600.
DF(4) +F	=DF(2) +F	5.0 - 9	0.75-	3600.
DF(4) +F	=DF(1) +F	3.3 - 9	0.75-	3600.
DF(4) +F	=DF(0) +F	2.5 - 9	0.75-	3600.
DF(5) +F	=DF(4) +F	1.2 - 8	0.75-	3600
DF(5) +F	=DF(3) +F	6.2 - 9	0.75-	3600.
DF(5) +F	=DF(2) +F	4.2 - 9	0.75-	3600.
DF(5) +F	=DF(1) +F	3.0 - 9	0.75-	3600.
DF(5) +F	=DF(0) +F	2.5 - 9	0.75-	3600.
DF(1) +DF(1)	=DF(0) +DF(2)	1.0 - 8	1.0	
DF(2) +DF(2)	=DF(1) +DF(3)	1.0 - 8	1.0	
DF(3) +DF(3)	=DF(2) +DF(4)	1.0 - 8	1.0	
DF(4) +DF(4)	=DF(3) +DF(5)	1.0 - 8	1.0	
DF(1) +DF(2)	=DF(0) +DF(3)	5.0 - 9	1.0	
DF(2) +DF(3)	=DF(1) +DF(4)	5.0 - 9	1.0	
DF(3) +DF(4)	=DF(2) +DF(5)	5.0 - 9	1.0	
DF(1) +DF(3)	=DF(0) +DF(4)	2.5 - 9	1.0	
DF(2) +DF(4)	=DF(1) +DF(5)	2.5 - 9	1.0	
DF(1) +DF(4)	=DF(0) +DF(5)	1.2 - 9	1.0	

Tabular Data B-1.C-8. Cold reaction F_2/D_2 model (127 reactions) (Continued).

Reaction		Products		A	N	B	M
DF(2)	+HF(0)	=DF(0)	+HF(1)	3.40-11	1.0		
DF(3)	+HF(0)	=DF(1)	+HF(1)	5.50-11	1.0		
DF(4)	+HF(0)	=DF(2)	+HF(1)	1.20-10	1.0		
DF(5)	+HF(0)	=DF(3)	+HF(1)	2.30-10	1.0		
DF(3)	+HF(0)	=DF(0)	+HF(2)	1.50-09	1.0		
DF(4)	+HF(0)	=DF(1)	+HF(2)	4.40-09	1.0		
DF(5)	+HF(0)	=DF(2)	+HF(2)	1.00-08	1.0		
DF(0)	+HF(3)	=DF(4)	+HF(0)	4.70-09	1.0		
DF(1)	+HF(3)	=DF(5)	+HF(0)	1.80-09	1.0		
DF(5)	+HF(0)	=DF(0)	+HF(3)	7.20-12	1.0		
HF(1)	+DF(0)	=HF(0)	+DF(1)	4.20-10	1.0		
HF(1)	+DF(1)	=HF(0)	+DF(2)	2.60-10	1.0		
HF(1)	+M17	=HF(0)	+M17	2.0 -15-0.5		53.	0.3333
HF(1)	+HF(1)	=HF(2)	+HF(0)	1.40-08	1.0		
HF(1)	+HF(2)	=HF(3)	+HF(0)	7.00-09	1.0		
HF(2)	+DF(0)	=HF(1)	+DF(1)	5.50-10	1.0		
HF(2)	+DF(1)	=HF(1)	+DF(2)	6.70-10	1.0		
HF(2)	+M17	=HF(1)	+M17	4.0 -15-0.50		53.	0.3333
HF(2)	+M17	=HF(0)	+M17	2.0 -15-0.5		53.	0.3333
HF(3)	+DF(0)	=HF(2)	+DF(1)	8.40-10	1.0		
HF(3)	+DF(1)	=HF(2)	+DF(2)	6.00-10	1.0		
HF(3)	+M17	=HF(2)	+M17	6.0 -15-0.5		53.	0.3333
HF(3)	+M17	=HF(1)	+M17	3.0 -15-0.5		53.	0.3333
HF(3)	+M17	=HF(0)	+M17	2.0 -15-0.5		53.	0.3333
H	+DF(1)	=HF(0)	+D	2.30-09	.74	-2240.0	
H	+DF(2)	=HF(0)	+D	1.90-09	.72	-2190.0	
H	+DF(2)	=HF(1)	+D	2.50-09	.74	-2160.0	
H	+DF(3)	=HF(0)	+D	1.40-09	.66	-2180.0	
H	+DF(3)	=HF(1)	+D	6.60-10	.58	-2220.0	
H	+DF(3)	=HF(2)	+D	2.90-09	.75	-2170.0	
H	+DF(4)	=HF(2)	+D	5.50-09	.68	-2190.0	
H	+DF(5)	=HF(3)	+D	7.20-09	.69	-2200.0	
H	+DF(1)	=DF(0)	+H	1.10-09	.69	-2125.0	
H	+DF(2)	=DF(0)	+H	1.10-09	.64	-2260.0	
H	+DF(2)	=DF(1)	+H	1.70-09	.67	-2300.0	
H	+DF(3)	=DF(0)	+H	6.60-09	.89	-2180.0	
H	+DF(3)	=DF(1)	+H	3.50-10	.58	-2240.0	
H	+DF(3)	=DF(2)	+H	4.20-09	.90	-2190.0	
H	+DF(4)	=DF(2)	+H	1.00-08	.79	-2190.0	
H	+DF(5)	=DF(3)	+H	1.20-08	.76	-2180.0	

Tabular Data B-1.C-8. Cold reaction F_2/D_2 model (127 reactions) (Concluded).

					A	N	B
HF(1)	+H		=HF(0)	+H	1.50-10	.28	-1170.0
HF(2)	+H		=HF(0)	+H	7.10-11	.08	- 900.0
HF(2)	+H		=HF(1)	+H	7.30-12	-.20	- 720.0
H	+F2		=HF(3)	+F	1.80-10		-2400.0
H	+F	+M3	=HF(3)	+M3	6.20-30	1.0	
H	+H	+M2	=H2	+M2	2.80-30	1.0	
H	+D	+M2	=HD	+M2	2.80-30	1.0	

Catalytic Species

M_1 = 2.4F, $2.4F_2$; All others: 1.0

M_2 = 20D, 20H, $1.75D_2$, $1.75H_2$, 1.75HD; All others: 1.0

M_3 = All species

M_4 = DF, 2HF

M_5 = N_2

M_6 = D_2, H_2, HD

M_7 = 2He, F_2, $4CF_4$, SF_6

M_{17} = 0.5DF, HF

AD-A071 360 ARMY MISSILE RESEARCH AND DEVELOPMENT COMMAND REDSTO--ETC F/G 20/5
COMPILATION OF DATA RELEVANT TO NUCLEAR PUMPED LASERS. VOLUME I--ETC(U)
DEC 78 E W MCDANIEL, M R FLANNERY, E W THOMAS

UNCLASSIFIED DRDMI-H-78-1-VOL-4 NL

2 OF 6
AD
A071360

Tabular Data B-1.C-9. DF/CO_2 transfer reaction model subset (38 reactions).

		A	N	B
DF(1) +CO2000	=DF(0) +CO2001	2.4 -10	0.7	
DF(2) +CO2000	=DF(1) +CO2001	4.0 -10	0.7	
DF(3) +CO2000	=DF(2) +CO2001	1.0 - 9	0.7	
DF(4) +CO2000	=DF(3) +CO2001	2.0 - 9	0.7	
DF(5) +CO2000	=DF(4) +CO2001	4.0 - 9	0.7	
DF(6) +CO2000	=DF(5) +CO2001	6.0 - 9	0.7	
DF(7) +CO2000	=DF(6) +CO2001	8.0 - 9	0.7	
DF(8) +CO2000	=DF(7) +CO2001	1.0 - 8	0.7	
DF(9) +CO2000	=DF(8) +CO2001	1.2 - 8	0.7	
CO2110+CO2000	=CO2100+CO2010	1.25-13	-0.5	
CO2030+CO2000	=CO2100+CO2010	1.8 -15	-0.5	
CO2030+CO2000	=CO2020+CO2010	3.1 -13	-0.5	
CO2100+CO2000	=CO2010+CO2010	4.0 -13		
CO2020+CO2000	=CO2010+CO2010	1.4 -12	-0.5	
CO2001+M4	=CO2110+M4	3.4 -11	0.7	
CO2001+M5	=CO2110+M5	1.1 -27	-4.8	1484.
CO2001+M9	=CO2110+M9	1.9 -31	-5.8	2436.
CO2001+M10	=CO2110+M10	2.0 -18	-1.5	
CO2001+M4	=CO2030+M4	1.7 -13		
CO2001+M5	=CO2030+M5	8.1 -31	-5.6	1484.
CO2001+M9	=CO2030+M9	1.4 -34	-6.6	2436.
CO2001+M10	=CO2030+M10	1.5 -21	-2.3	
CO2110+M11	=CO2030+M11	4.3 -17	-1.5	
CO2110+M11	=CO2020+M11	4.5 -27	-4.2	- 903.
CO2110+M11	=CO2020+M11	8.8 -20	-2.5	- 4410.
CO2110+M11	=CO2100+M11	8.6 -24	-3.8	- 549.
CO2030+M11	=CO2020+M11	9.3 -22	-3.3	- 1230.
CO2030+M11	=CO2100+M11	1.1 -21	-3.0	- 1060.
CO2100+M11	=CO2020+M11	7.9 -18	-1.5	
CO2100+M12	=CO2010+M12	5.65-22	-3.3	- 1480.
CO2100+M13	=CO2010+M13	1.8 -21	-3.0	843.
CO2100+M14	=CO2010+M14	2.7 -10	1.0	
CO2020+M12	=CO2010+M12	2.1 -21	-3.2	- 1350.
CO2020+M13	=CO2010+M13	3.8 -21	-3.0	843.
CO2020+M14	=CO2010+M14	5.8 -10	1.0	
CO2010+M12	=CO2000+M12	3.4 -26	-4.2	1130.
CO2010+M13	=CO2000+M13	9.9 -22	-3.0	843.
CO2010+M14	=CO2000+M14	1.5 -10	1.0	

Tabular Data B-1.C-9. DF/CO_2 transfer reaction model subset (38 reactions) (Concluded).

<u>Catalytic Species</u>

M_1 = 2.4F, $2.4F_2$; All others: 1.0

M_2 = 20D, $1.75D_2$; All others: 1.0

M_3 = All species

M_4 = DF, 2HF

M_5 = CO_2, N_2

M_6 = D_2

M_7 = Ar, 2He, F_2

M_8 = F

M_9 = Ar, 4D, $2F_2$, He, $2N_2$

M_{10} = D_2, 300F

M_{11} = 2D, $2D_2$, 1.5He; All others: 1.0

M_{12} = CO_2, DF, HF, 0.06Ar, F, F_2, $0.5N_2$

M_{13} = He

M_{14} = D, D_2

M_{15} = 1000 D, D_2

M_{16} = CO_2, DF, HF, Ar, F, F_2, He, N_2

Tabular Data B-1.C-10. $C\ell F_x/CS_2/D_2$ reaction model subset* (23 reactions).

					A		N	B
CL	+CL	+M3	=CL2	+M3	4.3	-31	1.0	1250.
CL	+F	+M3	=CLF	+M3	4.1	-32	1.0	1250.
D	+CL	+M3	=DCL	+M3	1.1	-31	1.0	
CL	+F2		=CLF	+F	9.1	-10		- 1400.
CL	+D2		=DCL	+D	8.0	-11		- 6700.
F	+CL2		=CLF	+CL	9.1	-10		- 1400.
D	+CL2		=DCL	+CL	2.0	-10		- 2400.
D	+CLF		=DCL	+F	6.0	-11		- 2400.
D	+CLF		=DF(4)	+CL	3.1	-11		- 2400.
F	+DCL		=DF(1)	+CL	2.5	-12		- 1500.
F	+DCL		=DF(2)	+CL	1.0	-11		- 1500.
F	+DCL		=DF(3)	+CL	2.4	-11		- 1500.
F	+DCL		=DF(4)	+CL	1.6	-11		- 1500.
H	+CL	+M3	=HCL	+M3	1.1	-31	1.0	
CL	+H2		=HCL	+H	8.0	-11		- 5260.0
H	+CL2		=HCL	+CL	2.0	-10		- 2400.0
H	+CLF		=HCL	+F	1.0	-10		- 2400.0
H	+CLF		=HF(0)	+CL	1.0	-12		- 2400.0
H	+CLF		=HF(1)	+CL	2.1	-12		- 2400.0
H	+CLF		=HF(2)	+CL	9.0	-11		- 2400.0
F	+HCL		=HF(0)	+CL	3.3	-12		- 900.0
F	+HCL		=HF(1)	+CL	1.4	-11		- 900.0
F	+HCL		=HF(2)	+CL	2.4	-11		- 900.0

Catalytic Species

M_1 = 2.4F, $2.4F_2$; All others: 1.0

M_2 = 20D, 20H, $1.75D_2$, $1.75H_2$, 1.75HD; All others: 1.0

M_3 = All species

M_4 = DF, 0.2DCℓ, 0.4HCℓ, 2HF

M_8 = F, Cℓ

M_{17} = 0.5DF, 0.1DCℓ, 0.2HCℓ, HF

*Note that M_8 replaces F in the DF (v) + F V-R, T relaxation reactions.

Tabular Data B-1.C-11. DF/HF, D/H V-V and isotopic exchange reaction model subset (47 reactions).

				A	N	B	M
DF(2)	+HF(0)	=DF(0)	+HF(1)	3.40-11	1.0		
DF(3)	+HF(0)	=DF(1)	+HF(1)	6.60-11	1.0		
DF(4)	+HF(0)	=DF(2)	+HF(1)	1.20-10	1.0		
DF(5)	+HF(0)	=DF(3)	+HF(1)	2.30-10	1.0		
DF(3)	+HF(0)	=DF(0)	+HF(2)	1.50-09	1.0		
DF(4)	+HF(0)	=DF(1)	+HF(2)	4.00-09	1.0		
DF(5)	+HF(0)	=DF(2)	+HF(2)	1.00-08	1.0		
DF(0)	+HF(3)	=DF(4)	+HF(0)	4.70-09	1.0		
DF(1)	+HF(3)	=DF(5)	+HF(0)	1.80-09	1.0		
DF(5)	+HF(0)	=DF(0)	+HF(3)	5.40-12	1.0		
HF(1)	+DF(0)	=HF(0)	+DF(1)	4.20-10	1.0		
HF(1)	+DF(1)	=HF(0)	+DF(2)	2.60-10	1.0		
HF(1)	+M17	=HF(0)	+M17	2.0 -15-0.5		53.	0.3333
HF(1)	+HF(1)	=HF(2)	+HF(0)	1.40-08	1.0		
HF(1)	+HF(2)	=HF(3)	+HF(0)	7.00-09	1.0		
HF(2)	+DF(0)	=HF(1)	+DF(1)	5.50-10	1.0		
HF(2)	+DF(1)	=HF(1)	+DF(2)	4.00-10	1.0		
HF(2)	+M17	=HF(1)	+M17	4.0 -15-0.50		53.	0.3333
HF(2)	+M17	=HF(0)	+M17	2.0 -15-0.5		53.	0.3333
HF(3)	+DF(0)	=HF(2)	+DF(1)	8.40-10	1.0		
HF(3)	+DF(1)	=HF(2)	+DF(2)	6.00-10	1.0		
HF(3)	+M17	=HF(2)	+M17	6.0 -15-0.5		53.	0.3333
HF(3)	+M17	=HF(1)	+M17	3.0 -15-0.5		53.	0.3333
HF(3)	+M17	=HF(0)	+M17	2.0 -15-0.5		53.	0.3333
H	+DF(1)	=HF(0)	+D	2.30-09	.74-	2240.0	
H	+DF(2)	=HF(0)	+D	1.90-09	.72-	2190.0	
H	+DF(2)	=HF(1)	+D	2.50-09	.74-	2160.0	
H	+DF(3)	=HF(0)	+D	1.40-09	.66-	2180.0	
H	+DF(3)	=HF(1)	+D	6.60-10	.58-	2220.0	
H	+DF(3)	=HF(2)	+D	2.90-09	.75-	2170.0	
H	+DF(4)	=HF(2)	+D	5.50-09	.68-	2190.0	
H	+DF(5)	=HF(3)	+D	7.20-09	.69-	2200.0	
H	+DF(1)	=DF(0)	+H	1.10-09	.69-	2125.0	
H	+DF(2)	=DF(0)	+H	1.10-09	.64-	2260.0	
H	+DF(2)	=DF(1)	+H	1.70-09	.67-	2300.0	
H	+DF(3)	=DF(0)	+H	6.60-09	.89-	2180.0	
H	+DF(3)	=DF(1)	+H	3.50-10	.58-	2240.0	
H	+DF(3)	=DF(2)	+H	4.20-09	.90-	2190.0	
H	+DF(4)	=DF(2)	+H	1.00-08	.79-	2160.0	
H	+DF(5)	=DF(3)	+H	1.20-08	.76-	2160.0	

Tabular Data B-1.C-11. DF/HF, D/H V-V and isotopic exchange reaction model subset (47 reactions) (Concluded).

					A	N	B
HF(1)	+H		=HF(0)	+H	1.50-10	.28	-1170.0
HF(2)	+H		=HF(0)	+H	7.10-11	.08	- 900.0
HF(2)	+H		=HF(1)	+H	7.30-12	-.20	- 720.0
H	+F2		=HF(3)	+F	1.80-10		-2400.0
H	+F	+M3	=HF(3)	+M3	6.20-30	1.0	
H	+H	+M2	=H2	+M2	2.80-30	1.0	
H	+D	+M2	=HD	+M2	2.80-30	1.0	

<u>Catalytic Species</u>

M_2 = 20D, 20H, 1.75D_2, 1.75H_2, 1.75HD; All others: 1.0

M_3 = All species

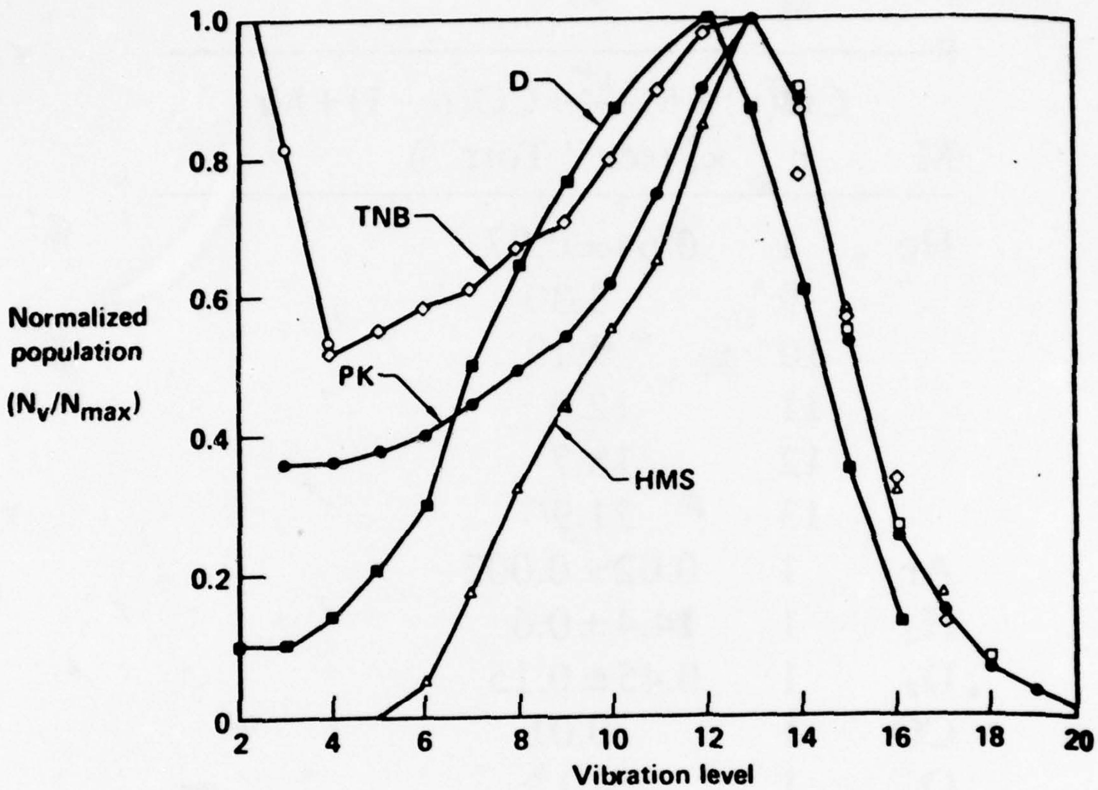
M_{17} = 0.5 DF, HF

Tabular Data B-1.C-12. Elementary reaction and kinetic data pertinent to the O-CS_2 chemical-laser system.

Reaction	Heat of reaction, ΔH°,[a] kcal/mol	Reaction rate constant, k_1,[b] cm^3/mol-sec
1. $O + CS_2 \rightarrow CS + SO$	−22.0	$5.00 \times 10^{13} \exp(-1.9/RT)$
2. $O + CS \rightarrow CO^* + S$	−85.0	$2.4 \times 10^{14} \exp(-2/RT)$
3. $S + O_2 \rightarrow SO + O$	−5.6	1.4×10^{12}
4. $SO + O_2 \rightarrow SO_2 + O$	−12.8	$3.5 \times 10^{11} \exp(-6.5/RT)$
5. $O + CS_2 \rightarrow COS + S$	−31.1	$1.0 \times 10^{14} \exp(-8/RT)$
6. $O + COS \rightarrow CO + SO$	−51.4	$1.9 \times 10^{13} \exp(-4.5/RT)$
7. $O + S_2 \rightarrow SO + S$	−22.1	4.0×10^{12}
8. $S + CS_2 \rightarrow CS + S_2$	+1.6	$1.0 \times 10^{14} \exp(-4/RT)$
9. $O_2 + CS \rightarrow CO + SO$	−90.0	$5.5 \times 10^{10} \exp(-2/RT)$
10. $O_2 + CS \rightarrow CPS + O$	−39.0	$1.0 \times 10^{13} \exp(-12/RT)$
11. $O_2 + CS_2 \rightarrow CS + SO_2$	24.0	$1.0 \times 10^{12} \exp(-43/RT)$
12. $S + COS \rightarrow CO + S_2$	−22.0	$1.9 \times 10^{13} \exp(-4.5/RT)$
13. $CS + SO \rightarrow CO + S_2$	−62.0	1.0×10^{9}
14. $O_3 + O \rightarrow 2O_2$	−93.7	$3.1 \times 10^{13} \exp(-5.7/RT)$
15. $O_3 + SO \rightarrow O_2 + SO_2$	−48.8	$1.5 \times 10^{12} \exp(-2.1/RT)$
16. $SO + O \rightarrow SO_2 + h\nu$		$4.5 \times 10^{10}/T$
		k_M(cm^6/mol^2-sec)
17. $O + O + M \rightarrow O_2 + M$	−119.1	$(4.6 \times 10^{17}/T) \exp(-0.172/T)$
18. $O + S + M \rightarrow SO + M$	−124.7	$K_{18} = K_{17}$
19. $S + S + M \rightarrow S_2 + M$	−101.7	$k_{19} = k_{17}$
20. $CO + O + M \rightarrow CO_2 + M$	−127.2	$5.9 \times 10^{15} \exp(-4.1/RT)$
21. $CS + S + M \rightarrow CS_2 + M$	−103.3	$k_{21} = k_{20}$
22. $CO + S + M \rightarrow COS + M$	−73.0	$k_{22} = k_{20}$
23. $O_2 + O + M \rightarrow O_3 + M$	−25.5	$1.7 \times 10^{13} \exp(2.1/RT)$
24. $O + SO + M \rightarrow SO_2 + M$	−131.9	$9.6 \times 10^{19}/T$

[a] Data obtained from JANAF Tables of Thermochemical Data,[95] with the exception that Okabe's[17] value for ΔH_f° for the CS was assumed.

[b] Activation energy E_A (kcal/mol); the gas constant R (kcal/mol-°K).



Chemical distribution of CO normalized to $N_{13} = 1.0$ versus vibrational level.

Note: HMS - Hancock, Morley, and Smith
TNB - Tsuchiya, Nielsen, and Bauer
PK - Powell and Kelley
D - Djeu

Graphical Data B-1.C-13. Chemical distribution of CO normalized to N_{13} = 1.0 versus vibrational level.

Tabular Data B-1.C-14. Experimental V→T rates for CO at 300°K.[a]

$$CO(v) + M \xrightarrow{k_v^M} CO(v-1) + M$$

M	v	k_v^M (sec^{-1} Torr^{-1})
He	1	0.64 ± 0.07
	9	5.30
	10	9.19
	11	12.0
	12	18.7
	13	21.9
Ar	1	0.02 ± 0.002
H_2	1	14.4 ± 0.6
D_2	1	0.45 ± 0.15
CO	1	0.01
O	1	610.[b]

[a] Rates listed are taken from Bronfin and Jeffers.

[b] Extrapolated to 300°K.

Tabular Data B-1.C-15. Experimental V→V rates for CO-diatomic molecule collisions at 300°K.

		$CO(v) + AB \xrightarrow{k_v^{AB}} CO(v-1) + AB^*$
AB	v	k_v^{AB} (sec^{-1} $Torr^{-1}$)
CO	2	$6.2 \pm 0.4 \times 10^4$
	3	$7.3 \pm 0.4 \times 10^4$
	4	$7.0 \pm 0.4 \times 10^4$
	5	$5.0 \pm 0.4 \times 10^4$
	6	$2.8 \pm 0.3 \times 10^4$
	7	$1.25 \pm 0.15 \times 10^4$
	8	$6.2 \pm 1.0 \times 10^3$
	9	$3.8 \pm 1.0 \times 10^3$
	10	$2.4 \pm 0.75 \times 10^3$
	11	$1.5 \pm 0.6 \times 10^3$
O_2	1	2.67 ± 0.46
	12	742
	13	1556
N_2	1	179 ± 26
	4	84.8
	5	60.1
	6	38.5
	7	30.0
	8	25.5
	9	17.3
	10	14.1
	11	7.8

[a]Rates are taken from Bronfin and Jeffers.

Tabular Data B-1.C-16. Experimental V→V rates for CO-triatomic molecule collisions at 300°K.

$$CO(v) + ABC \xrightarrow{k_v^{ABC}} CO(v-1) + ABC^*$$

ABC	v	k_v^{ABC} (sec^{-1} $Torr^{-1}$)
CS_2	1	$1.49 \pm 0.17 \times 10^4$
SO_2	1	11.6 ± 0.2
OCS	1	$2.63 \pm 0.48 \times 10^5$
	4	1.59×10^6
	5	2.12×10^6
	6	1.99×10^6
	7	1.27×10^6
	8	4.91×10^5
	9	2.51×10^5
	10	1.38×10^5
	11	1.09×10^5
	12	6.82×10^4
	13	3.50×10^4
N_2O	1	$1.51 \pm 0.13 \times 10^5$
	2	5.8×10^4
	3	3.0×10^4
	4	1.8×10^4
	5	7.8×10^3
	6	5.3×10^3
	7	3.46×10^3
	8	3.04×10^3
	9	3.04×10^3
	10	3.50×10^3
	11	3.82×10^3
	12	3.29×10^3
	13	3.29×10^3
CO_2	1	$2.0 \pm 0.1 \times 10^3$
	4	813
	5	601
	6	566
	7	537
	8	572
	9	742
	10	1.17×10^3
	11	1.87×10^3
	12	3.04×10^3
	13	4.24×10^3

*Rates are taken from Bronfin and Jeffers.

Tabular Data B-1.C-17. Collision cross sections for broadening of CO V-R optical transitions by various gases.

CO collision partner	Cross-section[a] ($cm^2 \times 10^{-14}$)
CO	1.10
He	0.30
Ar	0.96
H_2	0.35
N_2	1.04

[a]values listed for first [P(1)] rotational line; see D. Williams for variation with rotational quantum number.

Tabular Data B-1.C-18. Chemical reactions in an RI photodissociation laser[a].

Reactants	Products	$K\left(\frac{cm^3}{sec}\right)$ $R = CF_3$	$R = C_3F_7$
$I^* + RI$	$I + RI$	$5.4E-17$	$8.0E-18$
$I^* + R$	$I + R$	$3.7E-18$	
$I^* + R_2$	$I + R_2$	$4.7E-16$	
$I^* + O_2$	$I + O_2$	$8.6E-12$	
$I^* + I_2$	$I + I_2$	$1.3E-14e^{1650/T}$	
		$3.2E-12$	
$R + R$	R_2	$1.5E-11$	$1.0E-11$
$I + R$	RI	$5.0E-11$	
$I^* + R$	RI	$3.0E-12$	
$R + RI$	$R_2 + I$	$3.0E-16$	
$I^* + RI$	$I_2 + R$	$2.5E-19$	
$R + I_2$	$RI + I$	$4.0E-12$	
$I + RI$	$I_2 + R$	$1.6E-23$	
$2I + M$	$I_2 + M$	$4.3E-34$	
$2I + RI$	$I_2 + RI$	$7.0E-34e^{1600/T}$	$2.1E-33e^{1600/T}$
		$1.5E-31$	$4.5E-31$
$2I + He$	$I_2 + He$	$8.27E-29T^{-1.7}$	
		$4.6E-33$	
$2I + I_2$	$2I_2$	$1.1E-15T^{-5.9}$	
		$2.9E-30$	
$2I + O_2$	$I_2 + O_2$	$3.7E-32$	
$2I + R_2$	$I_2 + R_2$	$5.8E-32$	
$I^* + I + M$	$I_2 + M$	$4.3E-34$	
$I^* + I + RI$	$I_2 + RI$	$4.3E-34$	$1.6E-33$
$I^* + I + He$	$I_2 + He$	$9.4E-34$	$2.2E-33$
$I^* + I + I_2$	$2I_2$	$4.3E-32$	

[a]Unless otherwise mentioned, rate constants are given at 300°K. The data are taken from K. Hohla and K. L. Kompa.

Tabular Data B-1.C-19. Broadening coefficients β_M and rate coefficients k_m for collisional deactivation of I^*, tolerable pressures at which the deactivation reaches 10% in 10μsec, and cross sections σ.

M	$\beta_M/10^{15}$, cm^{-2} Torr^{-1}	Reference	$k_M/10^{-16}$, cm^3/sec	P_{10} Torr	$\sigma/10^{-19}$ cm^2 for P_{10}	$\sigma/10^{-19}$ cm^2 for 700 Torr
He	3.1	41	0.02	170,000		4.6
Ar	3.8	41				3.8
	3.6	44				4.0
	4.1	45				3.5
	3.55	38	0.02	170,000		4.0
N_2	5.1	38	2	1,700	1.15	2.8
CO	6.3	38	12	280	5.7	
CO_2	7.0	38	1.5	2,200	0.65	2.0
	7.3	38	4.6	700		1.95
SF_6	5.0	38	0.24	14,000		2.9
CF_2Cl_2	11.3	38	25	135	6.6	
CF_3I	8.7	38	2.2	1,500	0.77	1.64
			0.65			
i-C_3F_7I	15.5	38	8.0	420	1.5	
CF_3Br	5.4	38	—[a]	(600)[a]	3.1	
$(CF_3)_2CO$	14.4	38	—[a]	(350)[a]	2.0	
I, I*	12.5	38				

[a]Nonexponential decay is found with CF_3I. The data are taken from K. Hohla and K. L. Kompa.

Tabular Data B-1.C-20. Reaction rates for transfer chemical lasers.

Some Experimental Values at 300°K for Rate Constants for Reactions

$$HX(v=1)+CO_2(00^\circ 0) \underset{k_e'}{\overset{k_e}{\rightleftharpoons}} HX(v=0)+CO_2(00^\circ 1)$$

$$HX(v=1)+CO_2(00^\circ 0) \xrightarrow{k_{12}} HX(v=0)+CO_2(00^\circ 0)$$

System	Rate constants, $sec^{-1}\,Torr^{-1}$	Z^a	ΔE_v, cm^{-1}
HCl–CO_2	$k_e = 8.7\times10^4$	87	537
DCl–CO_2	$k_e = 2.9\times10^4$	262	−258
HBr–CO_2	$k_e = 2.8\times10^5$	26	209
DBr–CO_2	$k_e = 7.0\times10^2$	10,400	−540
HI–CO_2	$k_e = 1.3\times10^5$	57	−116
HF–CO_2	$k_e + k_{12} = 7.0\times10^4$	118	1612
HF–CO_2	$k_e + k_{12} = 3.6\times10^4$	230	1612
HF–CO_2	$k_e + k_{12} = 5.9\times10^4$	140	1612
DF–CO_2	$k_e + k_{12} = 2.4\times10^5$	34	558
DF–CO_2	$k_e + k_{12} = 1.5\times10^5$	54	558

[a] Approximate number of collisions for vibrational-energy transfer.

Tabular Data B-1.C-21. Reaction rates for transfer chemical lasers.

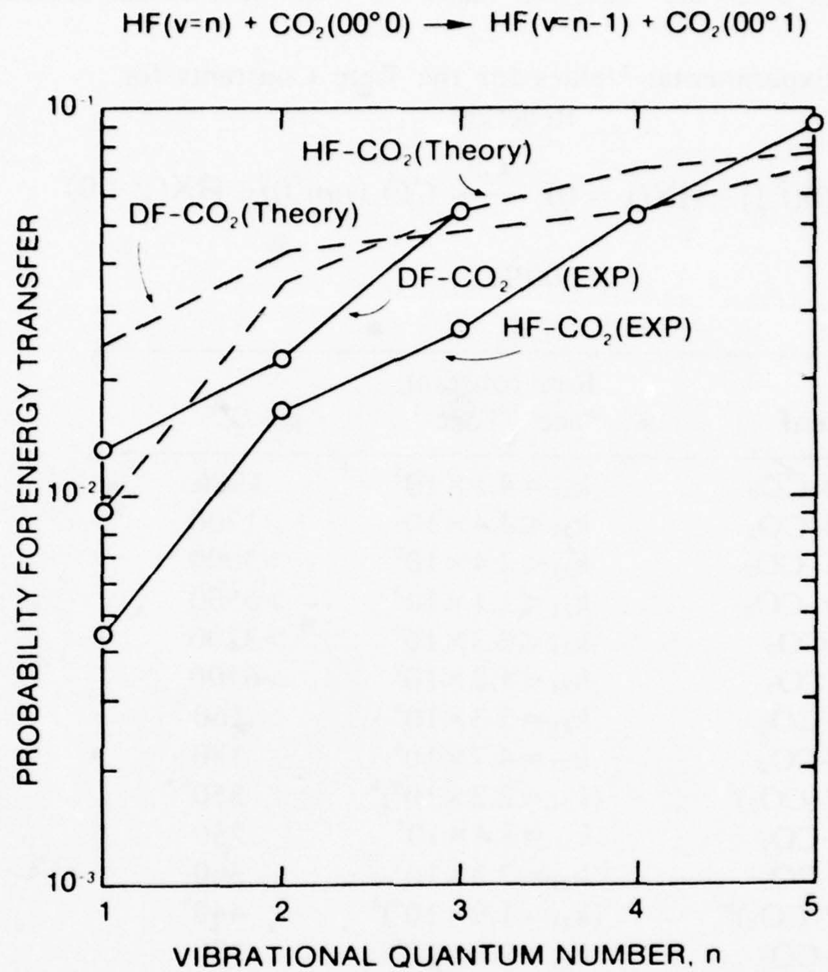
Some Experimental Values for the Rate Constants for Reaction

$$CO_2(00^01) + HX(v=0) \xrightarrow{k_{21}} CO_2(nm^l0) + HX(v=0)$$

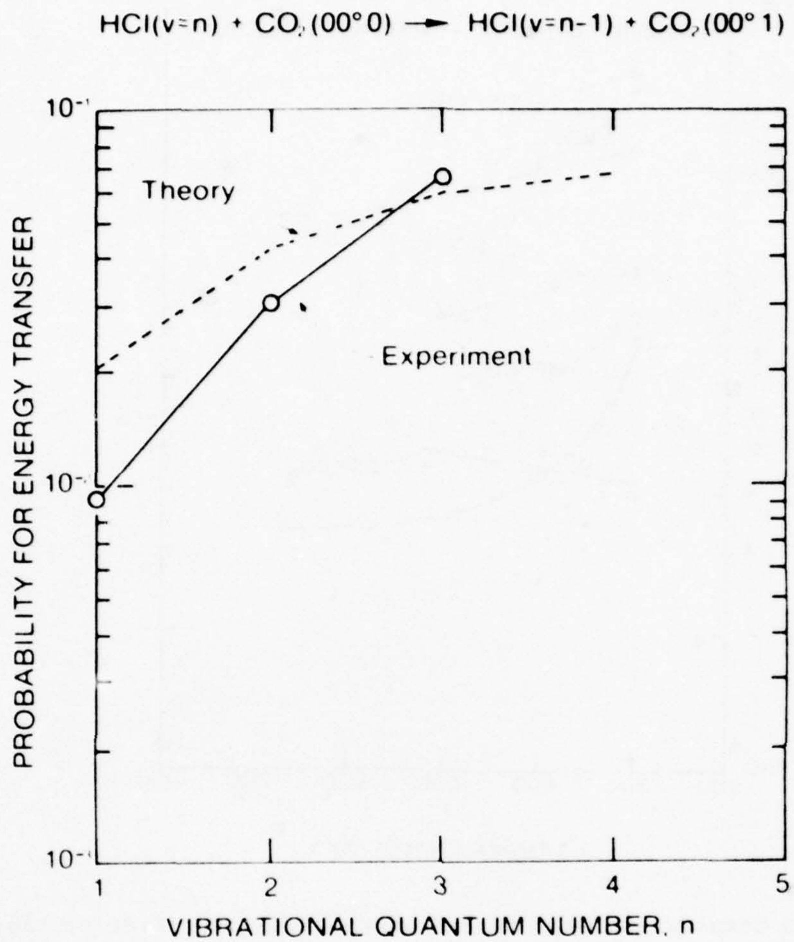
300°K

System	Rate constant, sec^{-1} $Torr^{-1}$	Z^a
$HCl-CO_2$	$k_{21} = 4.1 \times 10^3$	1900
$DCl-CO_2$	$k_{21} < 4.4 \times 10^3$	>1700
$HBr-CO_2$	$k_{21} < 2.4 \times 10^3$	>3000
$DBr-CO_2$	$k_{21} < 1.1 \times 10^3$	>6500
$HI-CO_2$	$k_{21} < 2.3 \times 10^3$	>3200
$DI-CO_2$	$k_{21} < 1.2 \times 10^3$	>6100
$HF-CO_2$	$k_{21} = 5.3 \times 10^4$	160
$HF-CO_2$	$k_{21} = 4.7 \times 10^4$	180
$(HF-CO_2)^b$	$(k_{21} = 2.2 \times 10^4)^b$	350^b
$HF-CO_2$	$k_{21} = 3.4 \times 10^4$	250
$DF-CO_2$	$k_{21} = 2.3 \times 10^4$	360
$(DF-CO_2)^b$	$(k_{21} = 1.9 \times 10^4)^b$	440^b
$DF-CO_2$	$k_{21} = 2.6 \times 10^4$	320

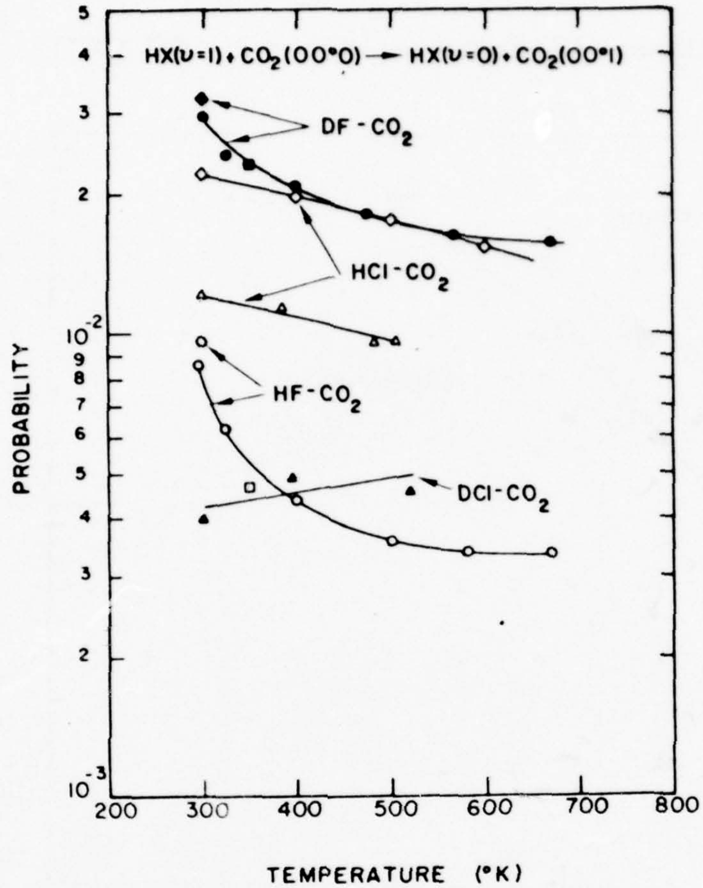
[a] Approximate number of collisions for vibrational deactivation.
[b] At $T = 350°K$.



Graphical Data B-1.C-22. Experimental probabilities for energy transfer between HF(DF) and CO_2 and the theory of Dillon and Stephenson.

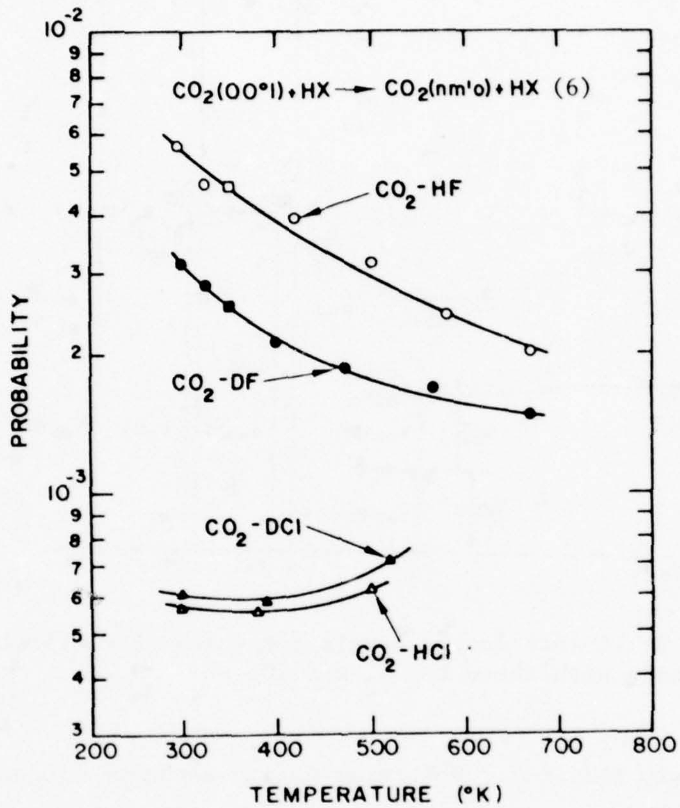


Graphical Data B-1.C-23. Comparison between measured probabilities for energy transfer between HCℓ and CO_2 and the theory of Dillon and Stephenson.



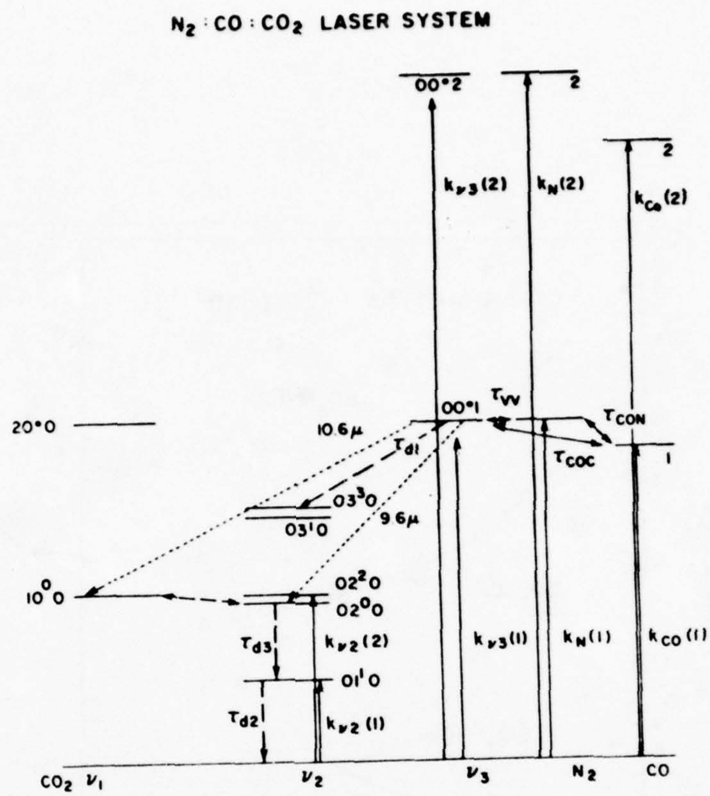
Comparison of the temperature dependences of the V→V,R transfer probabilities for the HCℓ-CO_2, DCℓ-CO_2, HF-CO_2, and DF-CO_2 systems: △, HCℓ-CO_2, Stephenson et al.; ▲, DCℓ-CO_2, Stephenson et al.; ◇, HCℓ-CO_2, Dillon and Stephenson; □, HF-CO_2, Stephens and Cool; ○, HF-CO_2, Cool; HF-CO_2, theory of Dillon and Stephenson; ■, DF-CO_2, Stephens and Cool; ●, DF-CO_2, Cool; ◆, DF-CO_2, theory of Dillon and Stephenson.

Graphical Data B-1.C-24. Temperature dependences of V→V,R transfer rates for transfer chemical lasers.



Comparison of the temperature dependences of the V→R,T deactivation probabilities of $CO_2(00°1)$ molecules by process (6) for HCℓ, DCℓ, HF, and Δ, CO_2-HCℓ, Stephenson et al.; ▲, CO_2-DCℓ, Stephenson et al.; ■, CO_2-DF Stephens and Cool; ●, CO_2-DF, Cool.

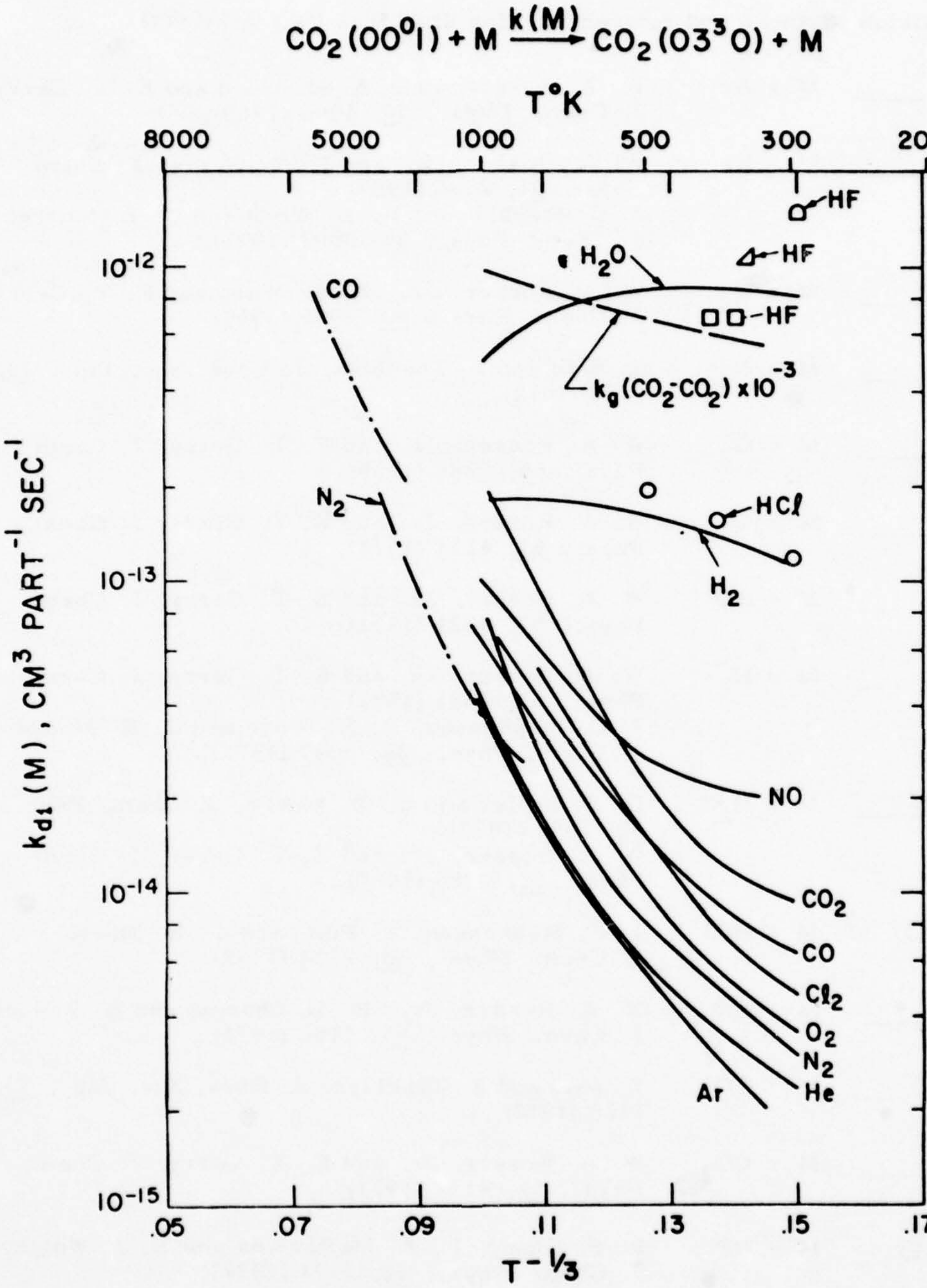
Graphical Data B-1.C-25. Temperature dependences of V→R,T transfer rates for transfer chemical lasers.



Graphical Data B-1.C-26. Energy levels for three vibrational modes in the CO_2 molecule with those for N_2 and CO.

Tabular Data B-1.C-27. Molecular energy exchange processes.

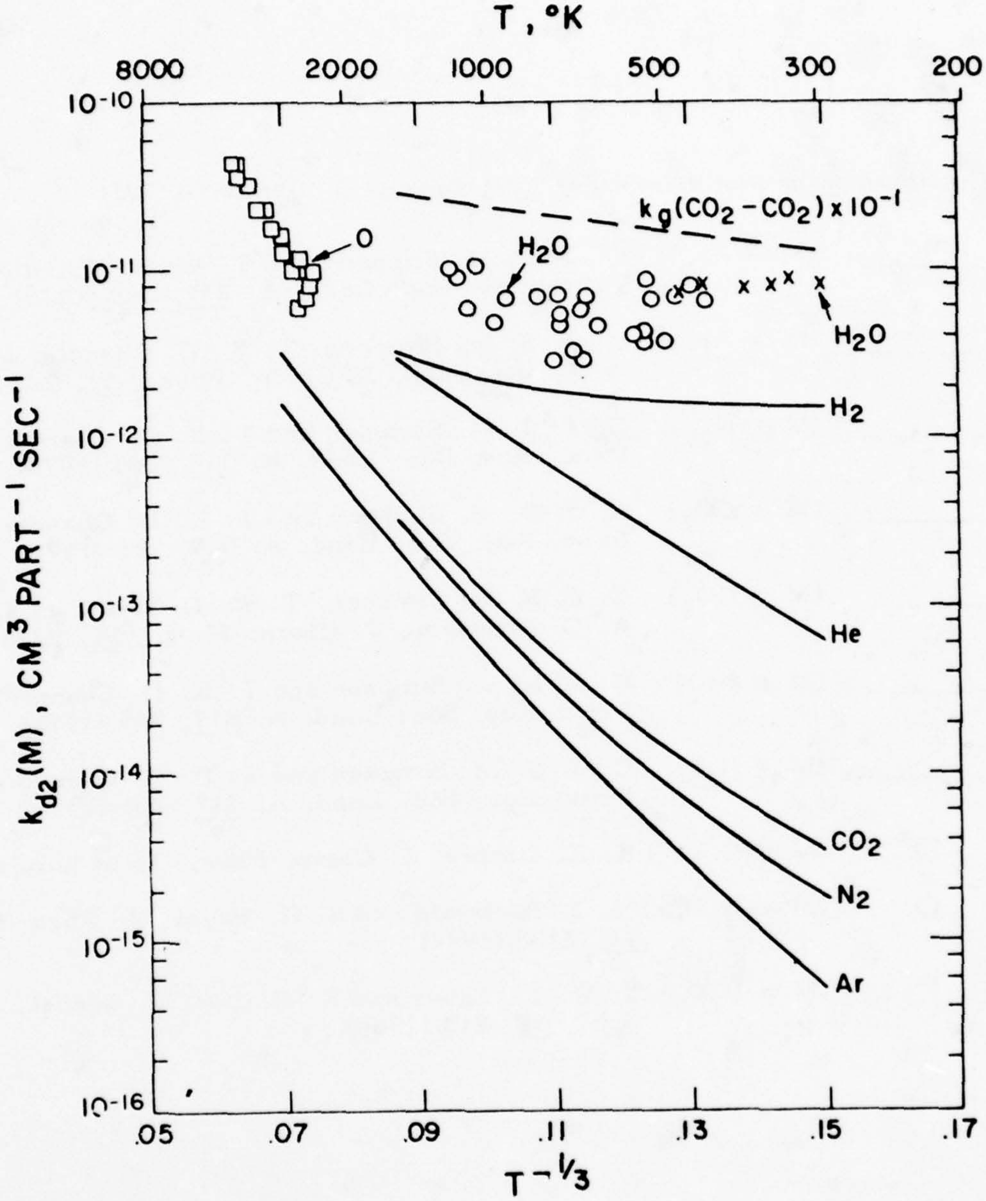
Process				Rate Constant	Characteristic Time
				$cm^3\ sec^{-1}$	atm sec
$CO_2(001)$	$+ M_j$	$\rightarrow CO_2(03^10)$	$+ M_j$	k_{d1j}	τ_{d1j}
$CO_2(01^10)$	$+ M_j$	$\rightarrow CO_2(000)$	$+ M_j$	k_{d2j}	τ_{d2j}
$CO_2(02^00)$	$+ CO_2(000)$	$\rightarrow CO_2(01^10)$	$+ CO_2(01^10)$	k_{d3c}	τ_{d3c}
$N_2(1)$	$+ CO_2(000)$	$\rightarrow N_2(0)$	$+ CO_2(001)$	k_{vv}	τ_{vv}
$N_2(1)$	$+ CO(0)$	$\rightarrow N_2(0)$	$+ CO(1)$	k_{CON}	τ_{CON}
$CO_2(001)$	$+ CO(0)$	$\rightarrow CO_2(000)$	$+ CO(1)$	k_{COC}	τ_{COC}
e	$+ CO(0)$	$\rightarrow$ e	$+ CO(1)$	$k_{CO}(1)$	$\tau_{CO}(1)$
e	$+ N_2(0)$	$\rightarrow$ e	$+ N_2(1)$	$k_N(1)$	$\tau_N(1)$
e	$+ CO_2(000)$	$\rightarrow$ e	$+ CO_2(001)$	$k_{\nu 3}(1)$	$\tau_{\nu 3}(1)$
e	$+ CO_2(000)$	$\rightarrow$ e	$+ CO_2(01^10)$	$k_{\nu 2}(1)$	$\tau_{\nu 2}(1)$



Graphical Data B-1.C-28. Values of k_{d1} as a function of temperature for various species of colliding molecule. (Collision partners and references are given on page 1462).

Collision partners and references (for Graphical Data B-1.C-28):

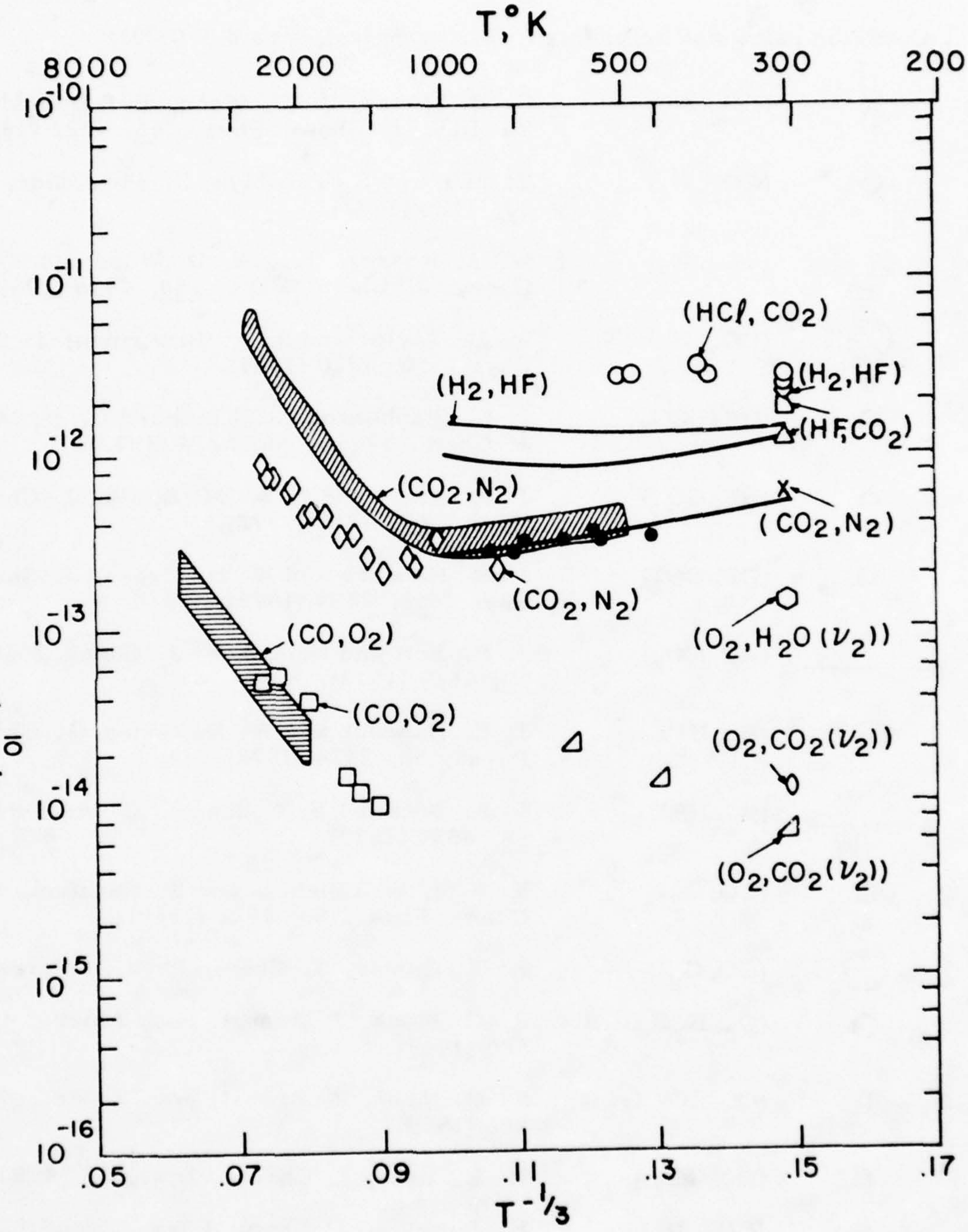
———	M = Ar	W. A. Rosser, Jr., A. D. Wood and E. T. Gerry, J. Chem. Phys., 50, 4996 (1969).
········ ———	M = He	W. A. Rosser, Jr. and E. T. Gerry, J. Chem. Phys., 51, 2286 (1969). J. C. Stephenson, R. E. Wood and C. B. Moore, J. Chem. Phys., 54, 3097 (1971).
———	M = N_2	W. A. Rosser, Jr., A. D. Wood and E. T. Gerry, J. Chem. Phys., 50, 4996 (1969).
— · —	M = N_2	Y. Sato and S. Tsuchiya, J. Phys. Soc. Jap., 33, 1120 (1972).
———	M = O_2	W. A. Rosser, Jr. and E. T. Gerry, J. Chem. Phys., 51, 2286 (1969).
———	M = Cl_2	W. A. Rosser, Jr. and E. T. Gerry, J. Chem. Phys., 51, 4131 (1971).
———	M = NO	W. A. Rosser, Jr. and E. T. Gerry, J. Chem. Phys., 51, 4131 (1971).
———	M = H_2	W. A. Rosser, Jr. and E. T. Gerry, J. Chem. Phys., 51, 4131 (1971). J. C. Stephenson, R. E. Wood and C. B. Moore, J. Chem. Phys., 54, 3097 (1971).
———	M = H_2O	D. F. Heller and C. B. Moore, J. Chem. Phys., 52, 1005 (1970). W. A. Rosser, Jr. and E. T. Gerry, J. Chem. Phys., 51, 2286 (1969).
○	M = HCl	J. C. Stephenson, J. Finzi and C. B. Moore, J. Chem. Phys., 56, 5214 (1972).
———	M = CO	W. A. Rosser, Jr., R. D. Sharma and E. T. Gerry, J. Chem. Phys., 54, 1196 (1971).
— · —	M = CO	Y. Sato and S. Tsuchiya, J. Phys. Soc. Jap., 33, 1120 (1972).
———	M = CO_2	W. A. Rosser, Jr. and E. T. Gerry, J. Chem. Phys., 51, 4131 (1971).
□	M = HF	R. S. Chang, R. A. McFarlane and B. J. Wolga, J. Chem. Phys., 56, 2474 (1972).
◘	M = HF	J. K. Hancock and W. H. Green, J. Chem. Phys., 56, 2474 (1972).
◺	M = HF	R. R. Stephens and T. A. Cool, J. Chem. Phys., 56, 5863 (1972).



Graphical Data B-1.C-29. Values of k_{d2} as a function of temperature for various species of colliding molecule. (Collision pairs and references are given on page 1464).

Collision pairs and references (For Graphical Data B-1.C-29):

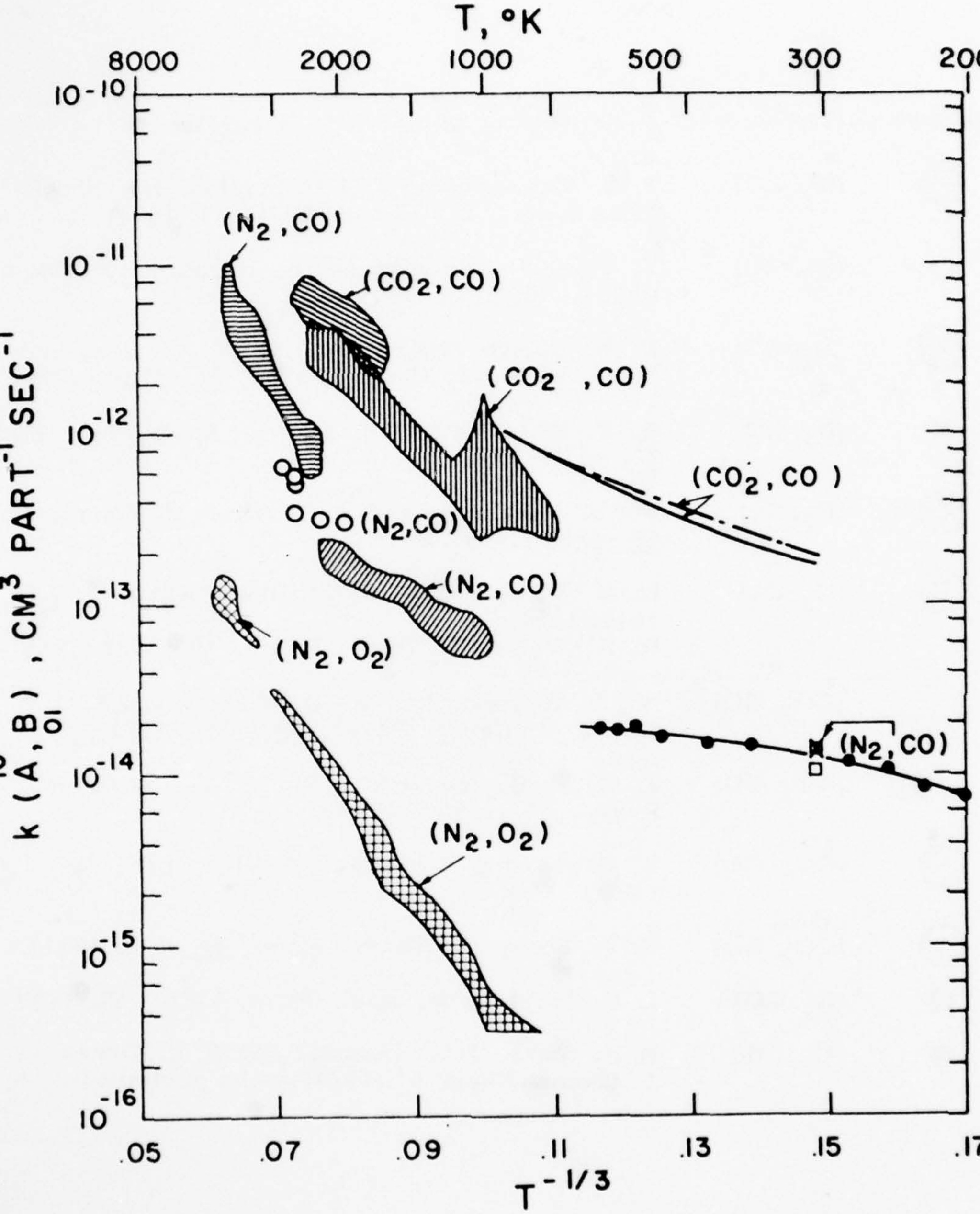
————	(M = Ar,)	C. J. S. M. Simpson and T. R. D. Chandler, Proc. Roy. Soc. Lond. A. 317, 265 (1970).
— — —	(M = Ar,)	C. J. S. M. Simpson, T. R. D. Chandler and A. C. Strawson, J. Chem. Phys., 51, 2214 (1969).
———--	(M = N_2,)	C. J. S. M. Simpson and T. R. D. Chandler, Proc. Roy. Soc. Lond. A. 317, 265 (1970).
————	(M = CO_2)	C. J. S. M. Simpson and T. R. D. Chandler, Proc. Roy. Soc. Lond. A. 317, 265 (1970).
————	(M = CO_2)	C. J. S. M. Simpson, T. R. D. Chandler and A. C. Strawson, J. Chem. Phys., 51, 2214 (1969).
————	(M = He,)	C. J. S. M. Simpson and T. R. D. Chandler, Proc. Roy. Soc. Lond. A. 317, 265 (1970).
————	(M = H_2,)	C. J. S. M. Simpson and T. R. D. Chandler, Proc. Roy. Soc. Lond. A. 317, 265 (1970).
□	(M = O,)	R. E. Center, J. Chem. Phys., to be published.
○	(M = H_2O,)	M. I. Buchwald and S. H. Bauer, J. Phys. Chem., 76, 3108 (1972).
×	(M = H_2O,)	J. W. L. Lewis and K. P. Lee, J. Acoust. Soc. Am., 38, 813 (1965).



Graphical Data B-1.C-30. Intermolecular vibrational transfer rate coefficient. (Collision pairs and references are given on page 1466).

Collision pairs and references (For Graphical Data B-1.C-30):

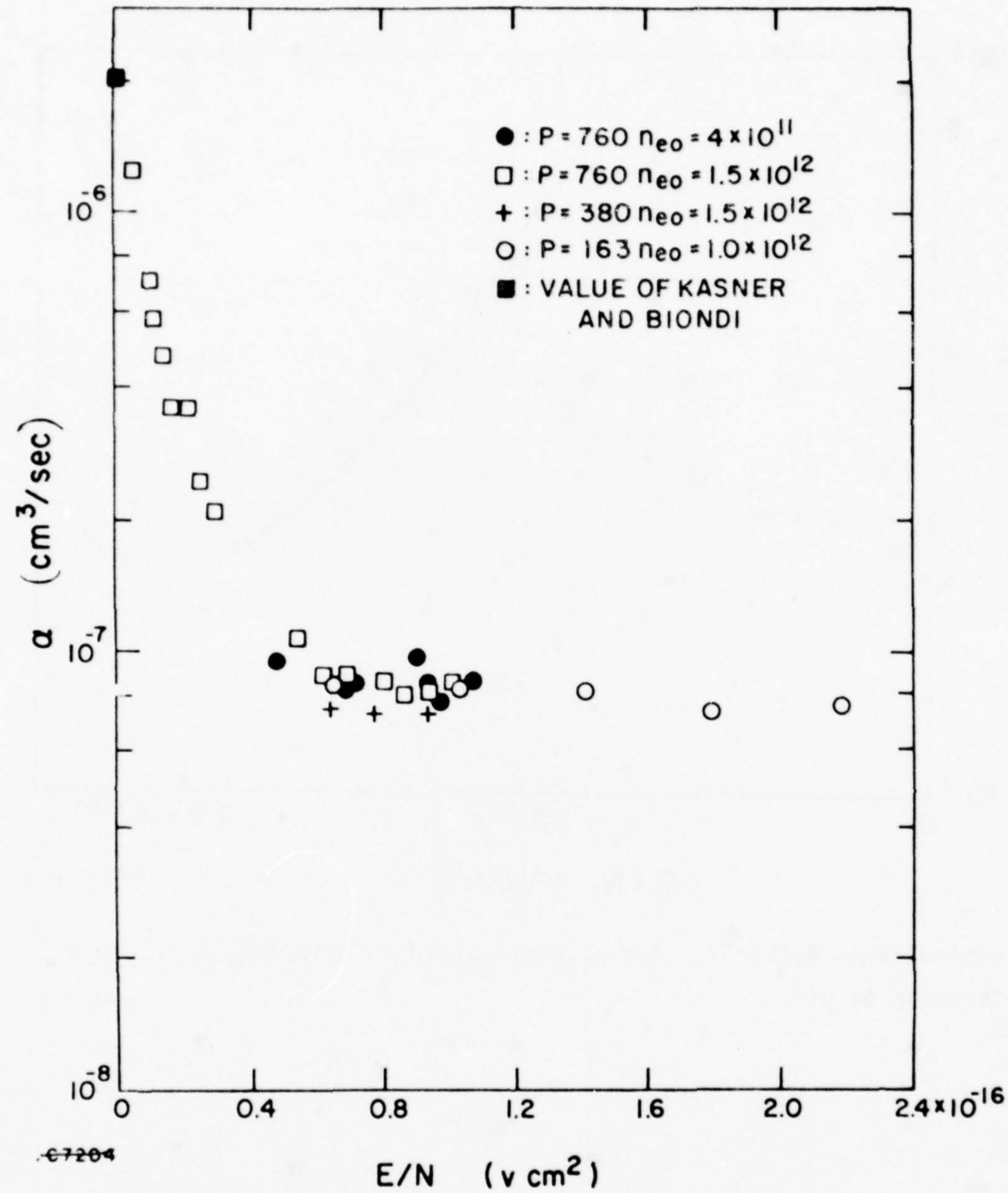
×	(CO_2, N_2)	C. B. Moore, R. E. Wood, B-L Hu and J. T. Yardley, J. Chem. Phys., 46, 4222 (1967).
◇	(CO_2, N_2)	Y. Sato and S. Tsuchiya, J. Phys. Soc. Jap., 33, 1120 (1972).
———	(CO_2, N_2)	W. A. Rosser, Jr., A. D. Wood and E. T. Gerry, J. Chem. Phys., 50, 4996 (1969).
⊘	(CO_2, N_2)	R. L. Taylor and S. A. Bitterman, J. Chem. Phys., 50, 1720 (1969).
○	(HCl, CO_2)	J. C. Stephenson, J. Finzi and C. B. Moore, J. Chem. Phys., 56, 5214 (1972).
△	(HF, CO_2)	J. R. Airey and I. W. M. Smith, J. Chem. Phys., 57, 1669 (1972).
D	(HF, CO_2)	J. K. Hancock and W. H. Green, J. Chem. Phys., 56, 2474 (1972).
———	(HF, CO_2)	J. F. Bott and N. Cohen, J. Chem. Phys., 58, 4539 (1973).
▽	(H_2, HF)	J. K. Hancock and W. H. Green, J. Chem. Phys., 56, 2474 (1972).
———	(H_2, HF)	J. F. Bott and N. Cohen, J. Chem. Phys., 58, 4539 (1973).
□	(CO, O_2)	Y. Sato, S. Tsuchiya and K. Kuratani, J. Chem. Phys., 50, 1911 (1969).
⊖	(CO, O_2)	R. E. Center, J. Chem. Phys., in press.
⬡	(O_2, H_2O (ν_2))	R. G. Monk, J. Acoust. Soc. Amer., 46, 580 (1969).
0	(O_2, CO_2 (ν_2))	R. G. Monk, J. Acoust. Soc. Amer., 46, 580 (1969).
◺	(O_2, CO_2 (ν_2))	H. E. Bass, J. Chem. Phys., 58, 4783 (1973).
●	(CO_2, N_2)	K. Bulthuis, J. Chem. Phys., 58, 5786 (1973).



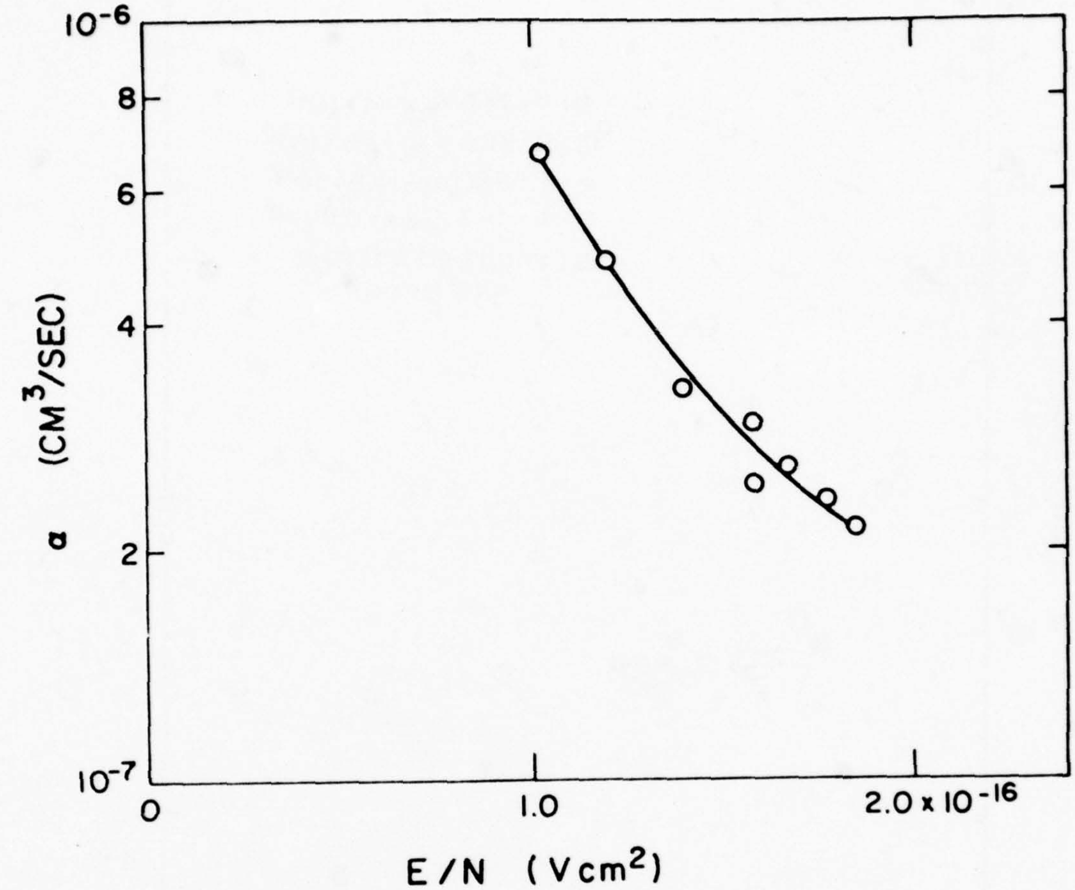
Graphical Data B-1.C-31. Intermolecular vibrational transfer rate coefficient. (Collision pairs and references are given on page 1468).

Collision pairs and references (For Graphical Data B-1.C-31):

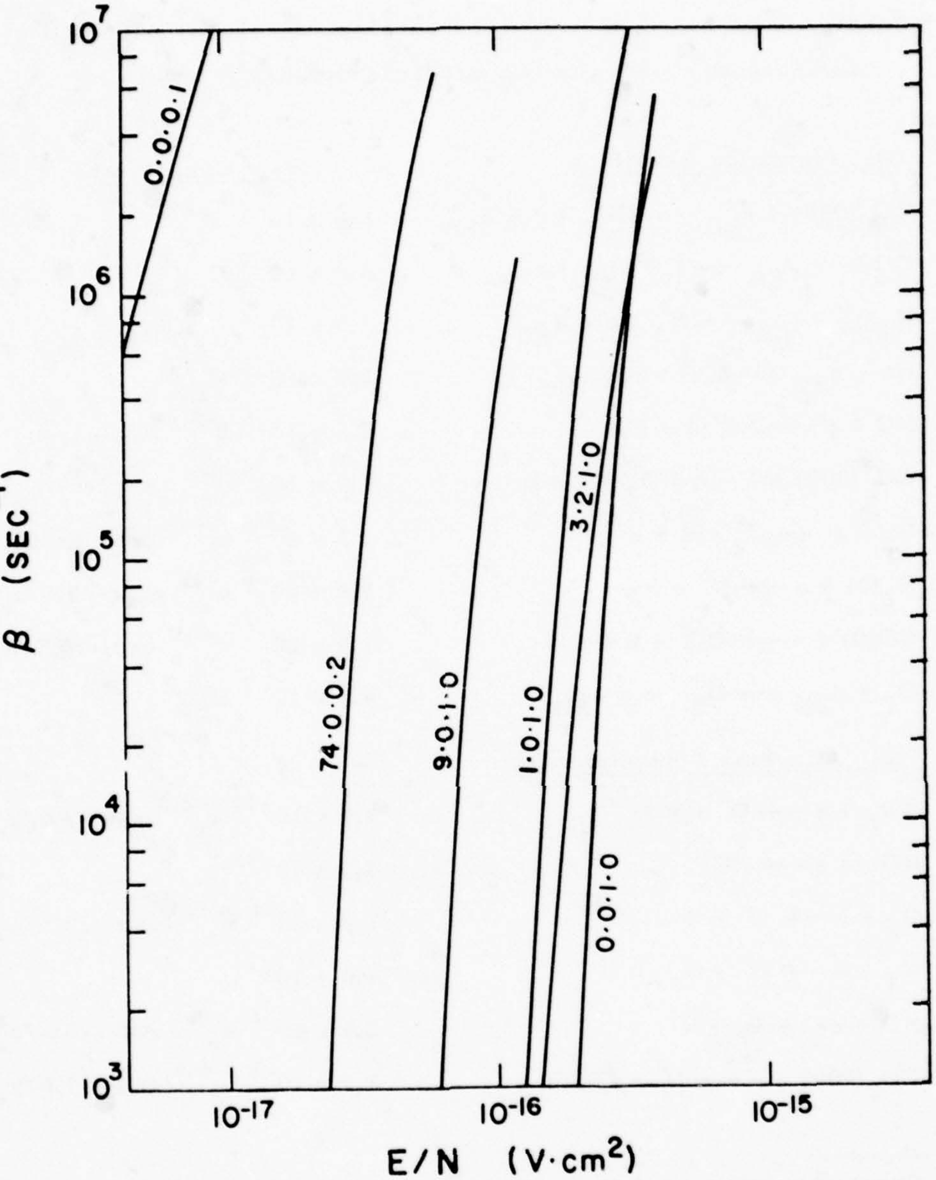
	(N_2, CO)	T. I. McLaren and J. P. Appleton, Int. Shock Tube Symp., 8th London 1971, 27 (1971).
○	(N_2, CO)	Y. Sato, S. Tsuchiya and K. Kuratani, J. Chem. Phys., 50, 1911 (1969).
	(N_2, CO)	C. W. vonRosenberg, Jr., K. N. C. Bray and N. H. Pratt, J. Chem. Phys., 56, 3230 (1972).
×	(N_2, CO)	P. F. Zittel and C. B. Moore, Appl. Phys. Lett., 21, 81 (1972).
	(N_2, O_2)	W. D. Breshears and P. F. Bird, J. Chem. Phys., 48, 4768 (1968).
	(N_2, O_2)	D. R. White and R. C. Millikan, AIAA J., 2, 1844 (1964). D. R. White, J. Chem. Phys., 49, 5472 (1968).
	(CO_2, CO)	W. A. Rosser, Jr., R. D. Sharma and E. T. Gerry, J. Chem. Phys., 54, 1196 (1971).
	(CO_2, CO)	J. C. Stephenson and C. B. Moore, J. Chem. Phys., 56, 1295 (1972).
	(CO_2, CO)	Y. Sato and S. Tsuchiya, J. Phys. Soc. Jap., 33, 1120 (1972).
	(CO_2, CO)	D. J. Seery, J. Chem. Phys., 56, 631 (1972).
□	(N_2, CO)	J. C. Stephenson, Appl. Phys. Lett., 576 (1973).
●	(N_2, CO)	D. F. Starr, J. K. Hancock and W. H. Green J. Chem. Phys. 61 (1974) (to be published).



Graphical Data B-1.C-32. Recombination rate in N_2 as a function of E/N.



Graphical Data B-1.C-33. Recombination rate in He:N_2:CO_2 3:2:1 as a function of E/N.



Graphical Data B-1.C-34. Attachment rates as a function of E/N at 300°K [Composition given by molar fraction in order He:N_2:CO_2:H_2O].

Tabular Data B-1.C-35. Ionized species reactions* and rate coefficients** for the CO_2 electric discharge laser.

	A. Ionization Reactions	Rate Coefficient
A1	$CO_2(000) + e_{EB} \rightarrow CO_2^+ + e + e_{EB}$	$6.9 \times 10^{-7} E_{EB}^{-2.0}$
A2	$CO(0) + e_{EB} \rightarrow CO^+ + e + e_{EB}$	$4.0 \times 10^{-7} E_{EB}^{-0.2}$
A3	$N_2(0) + e_{EB} \rightarrow N_2^+ + e + e_{EB}$	$3.7 \times 10^{-7} E_{EB}^{-0.2}$
A4	$He + e_{EB} \rightarrow He^+ + e + e_{EB}$	$6.5 \times 10^{-8} E_{EB}^{-0.2}$
A5	$NO + e \rightarrow NO^+ + e + e$	$4.3 \times 10^{-6} u_e^{-4.8} \exp(-15/u_e)$
A6	$CO_2(000) + e \rightarrow CO_2^+ + e + e$	$1.7 \times 10^{-5} u_e^{-6.3} \exp(-19/u_e)$
A7	$O_2 + e \rightarrow O_2^+ + e + e$	$1.5 \times 10^{-5} u_e^{-6.3} \exp(-19/u_e)$
A8	$N_2(0) + e \rightarrow N_2^+ e + e$	$7.2 \times 10^{-4} u_e^{-10} \exp(-25.4/u_e)$
A9	$CO(0) + e \rightarrow CO^+ + e + e$	$1.5 \times 10^{-5} u_e^{-6.0} \exp(-20.3/u_e)$
A10	$O_2 + e_{EB} \rightarrow O_2^+ + e + e_{EB}$	$4.2 \times 10^{-7} E_{EB}^{-0.2}$
	B. Attachment Reactions	
B1	$NO_2 + e \rightarrow O^- + NO$	$3.4 \times 10^{-10} u_e^{-2.4} \exp(-3.0/u_e)$
B2	$NO_2 + e \rightarrow NO_2^-$	4.0×10^{-11}
B3	$O_2 + e \rightarrow O^- + O$	$2.8 \times 10^{-6} u_e^{-7.9} \exp(-13.5/u_e)$
B4	$O_3 + e \rightarrow O^- + O_2$	4.0×10^{-11}
B5	$NO + e \rightarrow O^- + N$	$3.4 \times 10^{-6} u_e^{-8.2} \exp(-15.2/u_e)$
B6	$CO_2(000) + e \rightarrow O^- + CO(0)$	$8.4 \times 10^{-8} u_e^{-6.4} \exp(-11.6/u_e)$

*All forward reactions only

**Units are as follows: Rate coefficients, cm^3-particle-sec units; E_{EB}, keV; u_e, eV; T, °K; R, cal-mole^{-1} - °K^{-1}. (u_e is the <u>reduced</u> average electron energy, i.e., $u_e = k\,T_e$).

Tabular Data B-1.C-35. Ionized species reactions* and rate coefficients** for the CO_2 electric discharge laser (Continued).

B7	$O + e + M_1 \rightarrow O^- + M_1$	1.0×10^{-31}
B8	$O_2 + e + M_2 \rightarrow O_2^- + M_2$	1.0×10^{-31}
B9	$O_2 + e + M_3 \rightarrow O_2^- + M_3$	$4.2 \times 10^{-27}\ T^{-1} \exp(-1200/RT)$
B10	$H_2O + e \rightarrow OH^- + H$	$2.8 \times 10^{-6}\ u^{-7.2} \exp(-12.9/u_e)$
B11	$HNO_3 + e \rightarrow NO_2^- + OH$	5.0×10^{-8}
B12	$HNO_2 + e \rightarrow NO_2^- + H$	5.0×10^{-8}
B13	$N_2O_5 + e \rightarrow NO_3^- + NO_2$	5.0×10^{-8}
	C. Detachment Reactions	
C1	$O^- + CO(0) \rightarrow e + CO_2(020)$	$5.8 \times 10^{-9}\ T^{-0.4}$
C2	$O^- + O \rightarrow e + O_2$	1.9×10^{-10}
C3	$O^- + NO \rightarrow e + NO_2$	$1.8 \times 10^{-8}\ T^{-0.75}$
C4	$O^- + N \rightarrow e + NO$	2.2×10^{-10}
C5	$O_2^- + O \rightarrow e + O_3$	3.3×10^{-10}
C6	$O_2^- + N \rightarrow e + NO_2$	4.0×10^{-10}
C7	$O_3^- + O \rightarrow e + O_2 + O_2$	1.0×10^{-10}
C8	$O_3^- + O_3 \rightarrow e + O_3\ O_3$	1.0×10^{-10}
C9	$O^- + H_2 \rightarrow H_2O + e$	$2.5 \times 10^{-9}\ T^{-0.25}$
C10	$OH^- + H \rightarrow H_2O + e$	1.8×10^{-9}
C11	$OH^- + O \rightarrow HO_2 + e$	2.0×10^{-10}
C12	$O_2^- + H \rightarrow HO_2 + e$	1.5×10^{-9}
	D. Charge Transfer, Interchange and Clustering Reactions	
D1	$He^+ + CO_2(000) \rightarrow CO^+ + O + He$	1.2×10^{-9}
D2	$N_2^+ + CO_2(000) \rightarrow CO_2^+ + N_2(0)$	1.0×10^{-9}
D3	$CO^+ + CO_2(000) \rightarrow CO_2^+ + CO(0)$	1.2×10^{-9}
D4	$CO_2^+ + O_2 \rightarrow O_2^+ + CO_2(000)$	$1.1 \times 10^{-14}\ T \exp(1800/RT)$

Tabular Data B-1.C-35. Ionized species reactions* and rate coefficients** for the CO_2 electric discharge laser (Continued).

D5	$CO_2^+ + NO \rightarrow NO^+ + CO_2(000)$	1.2×10^{-10}
D6	$CO_2^+ + O \rightarrow O_2^+ + CO(0)$	2.6×10^{-10}
D7	$O_2^+ + NO \rightarrow NO^+ + O_2$	4.5×10^{-10}
D8	$O_2^+ + N \rightarrow NO^+ + O$	1.8×10^{-10}
D9	$O^- + O_3 \rightarrow O_3^- + O$	5.3×10^{-10}
D10	$O^- + NO_2 \rightarrow NO_2^- + O$	1.2×10^{-9}
D11	$O^- + O_2 + M_1 \rightarrow O_3^- + M_1$	$3.0 \times 10^{-28}\ T^{-1}$
D12	$O^- + NO + M_1 \rightarrow NO_2^- + M_1$	$3.0 \times 10^{-28}\ T^{-1}$
D13	$O^- + CO_2(000) + M_1 \rightarrow CO_3^- + M_1$	$5.0 \times 10^{-25}\ T^{-1}$
D14	$O^- + O_2 + M_4 \rightarrow O_3^- + M_4$	2.0×10^{-30}
D15	$O_2^- + O_3 \rightarrow O_3^- + O_2$	3.0×10^{-10}
D16	$O_2^- + NO_2 \rightarrow NO_2^- + O_2$	1.2×10^{-9}
D17	$O_2^- + O + M_1 \rightarrow O_3^- + M_1$	$3.0 \times 10^{-28}\ T^{-1}$
D18	$O_2^- + NO + M_1 \rightarrow NO_3^- + M_1$	$3.0 \times 10^{-28}\ T^{-1}$
D19	$O_3^- + O \rightarrow O_2^- + O_2$	1.0×10^{-10}
D20	$O_3^- + CO_2(000) \rightarrow CO_3^- + O_2$	6.0×10^{-10}
D21	$O_3^- + NO \rightarrow NO_3^- + O$	1.0×10^{-11}
D22	$O_3^- + NO_2 \rightarrow NO_3^- + O_2$	2.8×10^{-10}
D23	$CO_3^- + O \rightarrow O_2^- + CO_2(020)$	8.0×10^{-11}
D24	$CO_3^- + NO \rightarrow NO_2^- + CO_2(020)$	1.8×10^{-11}
D25	$CO_3^- + NO_2 \rightarrow NO_3^- + CO_2(000)$	2.0×10^{-10}
D26	$NO_2^- + NO_3 \rightarrow NO_3^- + NO_2$	3.0×10^{-10}
D27	$NO_2^- + O_3 \rightarrow NO_3^- + O_2$	1.8×10^{-11}
D28	$O_2^- + O_2 + M_1 \rightarrow O_4^- + M_1$	$2.0 \times 10^{-27}\ T^{-1.5}$

Tabular Data B-1.C-35. Ionized species reactions* and rate coefficients** for the CO_2 electric discharge laser (Continued).

D29	$O_2^- + CO_2(000) + M_3 \rightarrow CO_4^- + M_3$	5.2×10^{-29}
D30	$O_4^- + O \rightarrow O_3^- + O_2$	4.0×10^{-10}
D31	$O_4^- + CO_2(000) \rightarrow CO_4^- + O_2$	4.8×10^{-10}
D32	$O_4^- + NO \rightarrow NO_3^- + O_2$	2.5×10^{-10}
D33	$CO_4^- + O \rightarrow CO_3^- + O_2$	1.5×10^{-10}
D34	$CO_4^- + NO \rightarrow NO_3^- + CO_2(000)$	4.8×10^{-11}
D35	$CO_4^- + O_3 \rightarrow O_3^- + CO_2(000) + O_2$	1.3×10^{-10}
D36	$CO_2^+ + H \rightarrow HCO^+ + O$	6.0×10^{-10}
D37	$CO_2^+ + H_2 \rightarrow HCO_2^+ + H$	1.4×10^{-9}
D38	$CO_2^+ + H_2O \rightarrow HCO_2^+ + OH$	1.4×10^{-9}
D39	$HCO^+ + NO \rightarrow NO^+ + CHO$	1.2×10^{-10}
D40	$HCO^+ + H_2O \rightarrow H_3O^+ + CO(1)$	3.0×10^{-9}
D41	$HCO_2^+ + CO(0) \rightarrow HCO^+ + CO_2(020)$	3.0×10^{-9}
D42	$HCO_2^+ + H_2O \rightarrow H_3O^+ + CO_2(020)$	3.0×10^{-9}
D43	$O^- + H_2O \rightarrow OH^- + OH$	1.4×10^{-9}
D44	$O^- + HNO_3 \rightarrow NO_3^- + OH$	3.0×10^{-9}
D45	$OH^- + NO_2 \rightarrow NO_2^- + OH$	1.9×10^{-9}
D46	$O_2^- + OH \rightarrow OH^- + O_2$	6.0×10^{-10}
D47	$O_2^- + HNO_3 \rightarrow NO_3^- + HO_2$	2.8×10^{-9}
D48	$O_3^- + H \rightarrow OH^- + O_2$	8.4×10^{-10}
D49	$NO_2^- + H \rightarrow OH^- + NO$	3.7×10^{-10}
D50	$NO_2^- + HNO_3 \rightarrow NO_3^- + HNO_2$	1.6×10^{-9}
D51	$CO_3^- + H \rightarrow OH^- + CO_2(000)$	1.7×10^{-10}
D52	$CO_3^- + HNO_3 \rightarrow NO_3^- + OH + CO_2(000)$	8.0×10^{-10}
D53	$CO_4^- + H \rightarrow CO_3^- + OH$	2.2×10^{-10}

Tabular Data B-1.C-35. Ionized species reactions* and rate coefficients** for the CO_2 electric discharge laser (Continued).

E. Recombination Reactions

E1	$CO_2^+ + e \rightarrow CO(1) + O$	$2.0 \times 10^{-5}\ T^{-1.0}\ u_e^{-0.5}$
E2	$O_2^+ + e \rightarrow O + O$	$6.0 \times 10^{-7}\ T^{-0.5}\ u_e^{-0.5}$
E3*	$NO^+ + e \rightarrow N + O$	$1.2 \times 10^{-6}\ T^{-0.5}\ u_e^{-0.5}$
E3**	$NO^+ + e \rightarrow NO$	$3.0 \times 10^{-4}\ T^{-1.0}\ u_e^{-0.5}$
E4	$CO_2^+ + O_2^- \rightarrow CO(1) + O_2 + O$	6.0×10^{-7}
E5	$CO_2^+ + CO_3^- \rightarrow CO_2(020) + O + CO_2(020)$	5.0×10^{-7}
E6	$CO_2^+ + NO_2^- \rightarrow CO(1) + O + NO_2$	6.0×10^{-7}
E7	$CO_2^+ + NO_3^- \rightarrow CO(1) + O + NO_3$	5.0×10^{-7}
E8	$O_2^+ + O_2^- \rightarrow O_2 + O + O$	4.0×10^{-7}
E9	$O_2^+ + CO_3^- \rightarrow O_2 + O + CO_2(020)$	3.0×10^{-7}
E10	$O_2^+ + NO_2^- \rightarrow O + O + NO_2$	4.0×10^{-7}
E11	$O_2^+ + NO_3^- \rightarrow O + O + NO_3$	1.3×10^{-7}
E12	$NO^+ + O_2^- \rightarrow N + O + O_2$	6.0×10^{-7}
E13	$NO^+ + CO_3^- \rightarrow NO + O + CO_2(020)$	6.0×10^{-7}
E14	$NO^+ + NO_2^- \rightarrow N + O + NO_2$	5.0×10^{-7}
E15	$NO^+ + NO_3^- \rightarrow N + O + NO_3$	8.0×10^{-7}
E16	$CO_2^+ + O_4^- \rightarrow CO_2(020) + O_2 + O_2$	5.0×10^{-7}
E17	$CO_2^+ + CO_4^- \rightarrow CO_2(020) + CO_2(020) + O_2$	5.0×10^{-7}
E18	$O_2^+ + O_4^- \rightarrow O_2 + O_2 + O_2$	3.0×10^{-7}
E19	$O_2^+ + CO_4^- \rightarrow O_2 + CO_2(020) + O_2$	3.0×10^{-7}
E20	$NO^+ + O_4^- \rightarrow NO + O_2 + O_2$	6.0×10^{-7}
E21	$NO^+ + CO_4^- \rightarrow NO + CO_2(020) + O_2$	6.0×10^{-7}

*Dry
**Moist

Tabular Data B-1.C-35. Ionized species reactions* and rate coefficients** for the CO_2 electric discharge laser (Concluded).

E22	$HCO^+ + e \rightarrow H + CO(1)$	$1.0 \times 10^{-5}\ T^{-1}\ u_e^{-0.5}$
E23	$HCO_2^+ + e \rightarrow H + CO_2(020)$	$4.0 \times 10^{-5}\ T^{-1}\ u_e^{-0.5}$
E24	$H_3O^+ + e \rightarrow H + H + OH$	$4.0 \times 10^{-6}\ T^{-0.5}\ u_e^{-0.5}$
E25	$HCO^+ + O_2^- \rightarrow CO(1) + H + O_2$	3.0×10^{-7}
E26	$HCO^+ + CO_3^- \rightarrow CO(1) + CO_2(020) + OH$	3.0×10^{-7}
E27	$HCO^+ + CO_4^- \rightarrow CO(1) + CO_2(020) + HO_2$	3.0×10^{-7}
E28	$HCO_2^+ + O_2^- \rightarrow CO_2(020) + H + O_2$	1.2×10^{-6}
E29	$HCO_2^+ + CO_3^- \rightarrow CO_2(020) + CO_2(020) + OH$	1.0×10^{-6}
E30	$HCO_2^+ + CO_4^- \rightarrow CO_2(020) + CO_2(020) + HO_2$	1.0×10^{-6}
E31	$H_3O^+ + O_2^- \rightarrow H_2O + H + O_2$	2.4×10^{-6}
E32	$H_3O^+ + CO_3^- \rightarrow H_2O + CO_2(020) + OH$	2.4×10^{-6}
E33	$H_3O^+ + CO_4^- \rightarrow H_2O + CO_2(020) + HO_2$	2.4×10^{-6}
E34	$H_3O^+ + NO_3^- \rightarrow H_2O + NO_2 + OH$	2.4×10^{-6}
E35	$H_3O^+ + NO_2^- \rightarrow H_2O + NO_2 + H$	2.4×10^{-6}

Catalytic Species

M_1 = All species

M_2 = All species except O, O_2 and O_3

M_3 = O, O_2, O_3

M_4 = O_2

Tabular Data B-1.C-36. Excited species reactions and rate coefficients[a] for the CO_2 electric discharge laser.

A. Vibrational Pumping Reactions[b]

A1	$N_2(0) + e \rightarrow N_2(1) + e$	$\dfrac{1.6 \times 10^{-11} \exp(9.1\ u_e)}{1 + 7.0 \times 10^{-4} \exp(9.1\ u_e)}$
A2	$CO(0) + e \rightarrow CO(1) + e$	$\dfrac{2.4 \times 10^{-7} u_e^{0.5} \exp(-1.31/u_e)}{1 + 5.33\ u_e \exp(-1.31/u_e)}$
A3	$CO_2(000) + e \rightarrow CO_2(001) + e$	$7.9 \times 10^{-9} \exp(-0.38/u_e)$
A4	$CO_2(000) + e \rightarrow CO_2(010) + e$	$2.0 \times 10^{-8}\ u_e$

B. Electronic Pumping and De-Excitation Reactions[c]

B1	$CO(0) + e \rightarrow CO^* + e$	$5.3 \times 10^{-9} u_e^{0.5} \exp(-2.6/u_e)$
B2	$CO^* + M_1 \rightarrow CO(0) + M_1$	1.0×10^{-11}
B3	$CO^* + CO_2(000) \rightarrow CO(0) + O + CO(0)$	1.0×10^{-10}
B4	$N_2(0) + e \rightarrow N_2^* + e$	$1.3 \times 10^{-5} u_e^{-4.6} \exp(-11.5/u_e)$
B5	$N_2^* + M_1 \rightarrow N_2(0) + M_1$	1.0×10^{-11}
B6	$N_2^* + CO_2(000) \rightarrow N_2(0) + O + CO(0)$	1.0×10^{-11}
B7	$N_2^* + CO_2(000) \rightarrow N + NO + CO(0)$	1.0×10^{-10}
B8	$CO_2(000) + e \rightarrow CO_2^* + e$	$2.5 \times 10^{-9} u_e^{1.6} \exp(-5.1/u_e)$
B9	$CO_2^* + M_1 \rightarrow CO_2(000) + M_1$	1.0×10^{-11}
B10	$CO_2^* + CO_2(000) \rightarrow CO_2(000) + O + CO(0)$	1.0×10^{-10}

[a]Units are as follows: Rate coefficients, cm^3-particle-sec units; u_e, eV; T, ^oK; R, cal-mole^{-1} $^oK^{-1}$.

[b]All reversible reactions; $k_r = k_f/K$. For the vibrational pumping reactions, K is the equilibrium coefficient for the essentially thermo-neutral forward reaction involving hot electrons.

[c]All forward reactions only.

Tabular Data B-1.C-36. Excited species reactions and rate coefficients[a] for the CO_2 electric discharge laser (Continued).

C. Vibrational Relaxation Reactions[a]

C1	$CO_2(110) + CO_2(000) \rightarrow CO_2(100) + CO_2(010)$	$1.25 \times 10^{-13}\ T^{0.5}$
C2	$CO_2(030) + CO_2(000) \rightarrow CO_2(100) + CO_2(010)$	$1.8 \times 10^{-15}\ T^{0.5}$
C3	$CO_2(030) + CO_2(000) \rightarrow CO_2(020) + CO_2(010)$	$3.1 \times 10^{-13}\ T^{0.5}$
C4	$CO_2(100) + CO_2(000) \rightarrow CO_2(010) + CO_2(010)$	4.0×10^{-13}
C5	$CO_2(020) + CO_2(000) \rightarrow CO_2(010) + CO_2(010)$	$1.4 \times 10^{-12}\ T^{0.5}$
C6	$CO_2(001) + M_5 \rightarrow CO_2(110) + M_5$	$1.1 \times 10^{-27}\ T^{4.8}\ \exp(1484/RT)$
C7	$CO_2(001) + M_8 \rightarrow CO_2(110) + M_8$	$1.9 \times 10^{-31}\ T^{5.8}\ \exp(2436/RT)$
C8	$CO_2(001) + M_5 \rightarrow CO_2(030) + M_5$	$8.1 \times 10^{-31}\ T^{5.6}\ \exp(1484/RT)$
C9	$CO_2(001) + M_8 \rightarrow CO_2(030) + M_8$	$1.4 \times 10^{-34}\ T^{6.6}\ \exp(2436/RT)$
C10	$CO_2(110) + M_6 \rightarrow CO_2(030) + M_6$	$4.3 \times 10^{-17}\ T^{1.5}$
C11	$CO_2(110) + M_6 \rightarrow CO_2(020) + M_6$	$4.5 \times 10^{-27}\ T^{4.2}\ \exp(-903/RT)$
C12	$CO_2(110) + M_6 \rightarrow CO_2(020) + M_6$	$8.8 \times 10^{-20}\ T^{2.5}\ \exp(-4410/RT)$
C13	$CO_2(110) + M_6 \rightarrow CO_2(100) + M_6$	$8.6 \times 10^{-24}\ T^{3.8}\ \exp(-549/RT)$
C14	$CO_2(030) + M_6 \rightarrow CO_2(020) + M_6$	$9.3 \times 10^{-22}\ T^{3.3}\ \exp(-1230/RT)$
C15	$CO_2(030) + M_6 \rightarrow CO_2(100) + M_6$	$1.1 \times 10^{-21}\ T^{3.0}\ \exp(-1060/RT)$
C16	$CO_2(100) + M_6 \rightarrow CO_2(020) + M_6$	$8.0 \times 10^{-18}\ T^{1.5}$
C17	$CO_2(100) + M_7 \rightarrow CO_2(010) + M_7$	$5.6 \times 10^{-22}\ T^{3.3}\ \exp(-1480/RT)$
C18	$CO_2(100) + He \rightarrow CO_2(010) + He$	$1.8 \times 10^{-21}\ T^{3.0}\ \exp(843/RT)$
C19	$CO_2(100) + CO(0) \rightarrow CO_2(010) + CO(0)$	$8.4 \times 10^{-10}\ T^{-1.0}$
C20	$CO_2(020) + M_7 \rightarrow CO_2(010) + M_7$	$2.1 \times 10^{-21}\ T^{3.2}\ \exp(-1350/RT)$
C21	$CO_2(020) + He \rightarrow CO_2(010) + He$	$3.8 \times 10^{-21}\ T^{3.0}\ \exp(843/RT)$
C22	$CO_2(020) + CO(0) \rightarrow CO_2(101) + CO(0)$	$1.7 \times 10^{-9}\ T^{-1.0}$

[a]All reversible reactions.

Tabular Data B-1.C-36. Excited species reactions and rate coefficients[a] for the CO_2 electric discharge laser (Concluded).

C23	$CO_2(010) + M_7 \rightarrow CO_2(000) + M_7$	$3.4 \times 10^{-26}\ T^{4.2}\ \exp(1130/RT)$
C24	$CO_2(010) + He \rightarrow CO_2(000) + He$	$9.9 \times 10^{-22}\ T^{3.0}\ \exp(843/RT)$
C25	$CO_2(010) + CO(0) \rightarrow CO_2(000) + CO(0)$	$4.5 \times 10^{-10}\ T^{-1.0}$
C26	$CO_2(001) + N_2(0) \rightarrow CO_2(000) + N_2(1)$	$8.3 \times 10^{-12}\ T^{-0.5}$
C27	$CO_2(001) + CO(0) \rightarrow CO_2(000) + CO(1)$	$1.4 \times 10^{-17}\ T^{1.65}$
C28	$N_2(1) + CO(0) \rightarrow N_2(0) + CO(1)$	$2.7 \times 10^{-18}\ T^{1.5}$
C29	$CO_2(010) + H_2O \rightarrow CO_2(000) + H_2O$	$3.2 \times 10^{-13}\ \exp(22.9/T^{1/3})$
C30	$CO_2(001) + H_2O \rightarrow CO_2(030) + H_2O$	4.0×10^{-13}
C31	$N_2(1) + H_2O \rightarrow N_2(0) + H_2O$	$1.1 \times 10^{-10}\ \exp(-68.9/T^{1/3})$
C32	$CO(1) + H_2O \rightarrow CO(0) + H_2O$	$3.1 \times 10^{-10}\ \exp(-65.0/T^{1/3})$
C33	$CO_2(010) + H_2 \rightarrow CO_2(000) + H_2$	3.0×10^{-12}
C34	$CO_2(001) + H_2 \rightarrow CO_2(110) + H_2$	$1.7 \times 10^{-17}\ T^{1.5}$

Catalytic Species

M_1 = All species

M_5 = All species except He and N_2

M_6 = 1.5 He; All others: 1.0

M_7 = 0.5 N_2; CO = He = 0; All others: 1.0

M_8 = He, 2N_2

Tabular Data B-1.C-37. Free radical species reactions[a] and rate coefficients[b] for the CO_2 electric discharge laser.

A. Ternary Recombination Reactions		Rate Coefficients
A1	$N + N + M_9 \rightarrow N_2(1) + M_9$	8.3×10^{-34} exp(1000/RT)
A2	$N + O + M_9 \rightarrow NO + M_9$	1.8×10^{-31} $T^{-0.5}$
A3	$O + CO(0) + M_{10} \rightarrow CO_2(020) + M_{10}$	2.0×10^{-33} exp-(4000/RT)
A4	$O + O + M_9 \rightarrow O_2 + M_9$	3.8×10^{-30} T^{-1} exp-(340/RT)
A5	$O + O_2 + M_9 \rightarrow O_3 + M_9$	1.0×10^{-34} exp(1010/RT)
A6	$O + NO + M_9 \rightarrow NO_2 + M_9$	4.0×10^{-33} exp(1880/RT)
A7	$O + NO_2 + M_9 \rightarrow NO_3 + M_9$	1.8×10^{-32} exp(1000/RT)
A8	$H + H + M_9 \rightarrow H_2 + M_9$	2.8×10^{-30} $T^{-1.0}$
A9	$O + H + M_9 \rightarrow OH + M_9$	1.0×10^{-32}
A10	$H + OH + M_9 \rightarrow H_2O + M_9$	6.1×10^{-26} $T^{-2.0}$
A11	$H + O_2 + M_9 \rightarrow HO_2 + M_9$	2.1×10^{-32} exp(580/RT)
A12	$CHO + M_9 \rightarrow CO(0) + H + M_9$	1.2×10^{-10} exp(-15000/RT)
A13	$CH_2O + M_9 \rightarrow CO(0) + H_2 + M_9$	3.5×10^{-8} exp(-35000/RT)
A14	$HO_2 + NO + M_9 \rightarrow HNO_3 + M_1$	3.5×10^{-31}
A15	$OH + NO_2 \rightarrow HNO_3$	1.0×10^{-11} exp(-340/RT)
A16	$OH + NO \rightarrow HNO_2$	2.0×10^{-12}
A17	$NO_2 + NO_3 \rightarrow N_2O_5$	4.0×10^{-12}

[a] All reversible reactions.

[b] Units are as follows: Rate coefficients, cm^3-particle-sec units; T, ^oK; R, cal-mole^{-1}-$^oK^{-1}$.

Tabular Data B-1.C-37. Free radical species reactions[a] and rate coefficients[b] for the CO_2 electric discharge laser (Continued).

B. Binary Reactions

B1	$N + NO \rightarrow N_2(0) + O$	2.7×10^{-11}
B2	$N + NO_2 \rightarrow NO + NO$	1.4×10^{-12}
B3	$N + NO_3 \rightarrow NO + NO_2$	5.7×10^{-13}
B4	$N + O_2 \rightarrow NO + O$	1.1×10^{-14} T exp-(6300/RT)
B5	$N + O_3 \rightarrow NO + O_2$	5.7×10^{-13}
B6	$O + O_3 \rightarrow O_2 + O_2$	1.9×10^{-11} exp-(4600/RT)
B7	$O + NO_2 \rightarrow O_2 + NO$	1.6×10^{-10} $T^{-0.5}$
B8	$O + NO_3 \rightarrow O_2 + NO_2$	5.7×10^{-13}
B9	$NO + NO_3 \rightarrow NO_2 + NO_2$	8.7×10^{-12}
B10	$NO + O_3 \rightarrow NO_2 + O_2$	9.0×10^{-13} exp-(2400/RT)
B11	$NO_2 + O_3 \rightarrow NO_3 + O_2$	1.2×10^{-13} exp-(4900/RT)
B12	$NO_2 + NO_3 \rightarrow NO_2 + O_2 + NO$	2.3×10^{-13} exp-(3200/RT)
B13	$NO_3 + NO_3 \rightarrow NO_2 + O_2 + NO_2$	5.0×10^{-12} exp-(6000/RT)
B14	$OH + CO(0) \rightarrow CO_2(000) + H$	1.1×10^{-19} T^2 exp(1600/RT)
B15	$OH + H_2 \rightarrow H_2O + H$	1.0×10^{-17} T^2 exp(-2900/RT)
B16	$OH + HNO_2 \rightarrow H_2O + NO_2$	3.5×10^{-13} exp(-600/RT)
B17	$OH + HNO_3 \rightarrow H_2O + NO_3$	3.5×10^{-13} exp(-600/RT)
B18	$OH + N \rightarrow NO + H$	5.3×10^{-11}
B19	$H + NO_2 \rightarrow OH + NO$	6.0×10^{-10} exp(-1500/RT)
B20	$OH + O \rightarrow H + O_2$	4.0×10^{-11}
B21	$OH + OH \rightarrow H_2O + O$	1.0×10^{-11} exp(-1100/RT)
B22	$H + O_3 \rightarrow OH + O_2$	2.6×10^{-11}
B23	$OH + O_3 \rightarrow HO_2 + O_2$	1.6×10^{-12} exp(-2000/RT)

Tabular Data B-1.C-37. Free radical species reactions[a] and rate coefficients[b] for the CO_2 electric discharge laser (Concluded).

B24	$O + N_2O_5 \rightarrow NO_2 + NO_2 + O_2$	1.0×10^{-14}
B25	$HO_2 + H \rightarrow OH + OH$	4.2×10^{-10} exp(-1900/RT)
B26	$HO_2 + H \rightarrow H_2 + O_2$	4.2×10^{-11} exp(-700/RT)
B27	$HO_2 + NO \rightarrow NO_2 + OH$	2.0×10^{-13}
B28	$HO_2 + O \rightarrow OH + O_2$	8.0×10^{-11} exp(-1000/RT)
B29	$HO_2 + OH \rightarrow H_2O + O_2$	8.3×10^{-11} exp(-1000/RT)
B30	$HO_2 + O_3 \rightarrow OH + O_2 + O_2$	1.0×10^{-13} exp(-2500/RT)
B31	$CH_2O + H \rightarrow CHO + H_2$	2.2×10^{-11} exp(-3800/RT)
B32	$CH_2O + O \rightarrow CHO + OH$	1.6×10^{-13}
B33	$CH_2O + OH \rightarrow CHO + H_2O$	$9.0 \times 10^{-13}\ T^{0.5}$
B34	$CHO + O \rightarrow CO(0) + OH$	2.1×10^{-10}
B35	$CHO + OH \rightarrow CO(0) + H_2O$	2.1×10^{-10}
B36	$CHO + O_2 \rightarrow CO(0) + HO_2$	8.3×10^{-11} exp(-1600/RT)

Catalytic Species

M_9 = 2 CO_2, He; All others: 1.0

M_{10} = 3 CO_2, 1.5 CO; 20 O_2; All others: 1.0

Tabular Data B-1.C-38. Dominant formation kinetics for ArF^*.

$\vec{e} + Ar \rightarrow Ar^+ + \vec{e} + e_s$	
$e_s + F_2 \rightarrow F^- + F$	5×10^{-9} cm^3/sec[a]
$F^- + Ar^+ + (M) \rightarrow ArF^* + (M)$	
High pressure	
$Ar^+ + 2Ar \rightarrow Ar_2^+ + Ar$	2.5×10^{-31} cm^6/sec[b]
$Ar_2^+ + F^- \rightarrow ArF^* + Ar$	

[a]Hao-Lin Chen, R.E. Center, Daniel W. Trainor, and W.I. Fyfe, Ap; '. Phys. Lett. 30, 99 (1977).
[b]E.W. McDaniel, V. Cermak, A. Dalgarno, E.E. Ferguson, and L. Friedman, *Ion-Molecule Reactions* (Wiley-Interscience, New York, 1970), p. 338.

Tabular Data B-1.C-39. Dominant quenching kinetics of ArF^*.

Reaction	(Rate constant) $\times$(ArF^* lifetime)	Rate constant[a]
$ArF^* + F_2 \rightarrow$ Products	$7.6 \pm 0.7 \times 10^{-18}$ cm^3	1.9×10^{-9} cm^3/sec
$ArF^* + Kr \rightarrow KrF^* + Ar$	$6.1 \pm 1.5 \times 10^{-18}$ cm^3	1.6×10^{-9} cm^3/sec
$ArF^* + Xe \rightarrow XeF^* + Ar$	$1.8 \pm 0.2 \times 10^{-17}$ cm^3	4.5×10^{-9} cm^3/sec
$ArF^* + Ar \rightarrow$ Products	$3.6 \pm 1 \times 10^{-20}$ cm^3	9×10^{-12} cm^3/sec
$ArF^* + 2Ar \rightarrow Ar_2F^* + Ar$	$1.6 \pm 0.3 \times 10^{-39}$ cm^6	4×10^{-31} cm^6/sec

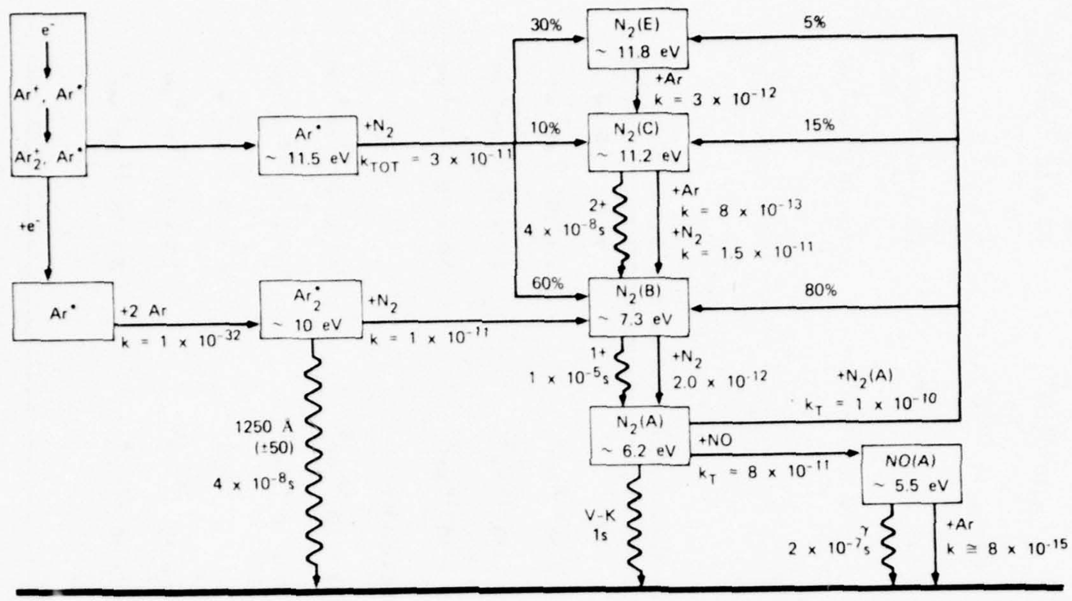
[a]The rate constants have been evaluated assuming an ArF^* lifetime of 4 ns

Tabular Data B-1.C-40. Dominant quenching processes of KrF^*.

REACTION	$k\tau_R$ (KrF^*)	$k(\tau_R = 6.5$ nsec)
$KrF^* + F_2 \rightarrow$ PRODUCTS	5×10^{-18} cm^3	7.8×10^{-10} cm^3 sec^{-1}
$KrF^* + 2Kr \rightarrow Kr_2F^* + Kr$	4.4×10^{-39} cm^6	6.7×10^{-31} cm^6 sec^{-1}
$KrF^* + Kr \rightarrow$ PRODUCTS	$\leq 1.1 \times 10^{-20}$ cm^3	
$KrF^* + Kr + Ar \rightarrow Kr_2F^* + Ar$	4.2×10^{-39} cm^6	6.5×10^{-31} cm^6 sec^{-1}
$KrF^* + 2Ar \rightarrow$ PRODUCTS	4.6×10^{-40} cm^6	7×10^{-32} cm^6 sec^{-1}

Tabular Data B-1.C-41. Dominant XeF^* quenching processes.

REACTION	$k\tau_r$	$k(\tau_r = 16$ ns)
$XeF^* + F_2$	5.3×10^{-18} cm^3	3×10^{-10} cm^3/sec
$XeF^* + NF_3$	2.8×10^{-19} cm^3	1.7×10^{-11} cm^3/sec
$XeF^* + Xe$	4.5×10^{-19} cm^3	2.9×10^{-11} cm^3/sec
$XeF^* + Ne$	NEGLIGIBLE	
$XeF^* + Xe + Ne$	1.23×10^{-38} cm^6	7.7×10^{-31} cm^6/sec
$XeF^* + 2Ne$	4.32×10^{-41} cm^6	2.7×10^{-33} cm^6/sec
$XeF^* + Ar$	1.28×10^{-20} cm^3	8×10^{-13} cm^3/sec
$XeF^* + 2Ar$	2.4×10^{-40} cm^6	1.5×10^{-32} cm^6/sec
$XeF^* + Xe + Ar$	4.8×10^{-39} cm^6	3×10^{-31} cm^6/sec



Graphical Data B-1.C-42. Detailed flow chart for the Ar - N_2 - NO *e*-beam pumped system.

Tabular Data B-1.C-43. Rate coefficients for the Ar - N_2 - NO e-beam pumped system.

Reaction No.	Reaction	Rate Coefficient
	Excitation Reactions	
1	$Ar^+ + 2Ar \rightarrow Ar_2^+ + Ar$	2.5×10^{-31} cm^6/sec
2	$Ar_2^+ + e^- \rightarrow Ar^* + Ar$	1×10^{-6} cm^3/sec
3	$Ar^* + 2Ar \rightarrow Ar_2^* + Ar$	1×10^{-32} cm^6/sec
4	$Ar^* + Ar^* \rightarrow Ar^+ + Ar + e^-$	5×10^{-10} cm^3/sec
5	$Ar_2^* + e^- \rightarrow 2Ar + e^-$	1×10^{-9} cm^3/sec
6	$Ar_2^* + Ar_2^* \rightarrow Ar_2^+ + 2Ar + e^-$	5×10^{-10} cm^3/sec
7	$Ar_2^* \rightarrow 2Ar + h\nu$	2.4×10^{7} s^{-1}
	Transfer Reactions	
8	$Ar^* + N_2 \rightarrow$ total	3×10^{-11} cm^3/sec
9	" $\rightarrow N_2(B) + Ar$	1.7×10^{-11} cm^3/sec
10	" $\rightarrow N_2(C) + Ar$	3×10^{-12} cm^3/sec
11	" $\rightarrow N_2(E) + Ar$	1×10^{-11} cm^3/sec
12	$Ar_2^* + N_2 \rightarrow N_2(B) + 2Ar$	1×10^{-11} cm^3/sec
	N_2 Triplet Reactions	
13	$N_2(E) + Ar \rightarrow N_2(C) + Ar$	3×10^{-12} cm^3/sec
14	$N_2(C) \rightarrow N_2(B) + h\nu$	$2.2\times10^{+7}$ s^{-1}
15	$N_2(C) + N_2 \rightarrow N_2(B) + N_2$	1.5×10^{-11} cm^3/sec
16	$N_2(C) + Ar \rightarrow N_2(B) + Ar$	8×10^{-13} cm^3/sec
17	$N_2(B) \rightarrow N_2(A) + h\nu$	1.1×10^{5} s^{-1}
18	$N_2(B) + N_2 \rightarrow N_2(A) + N_2$	2.0×10^{-12} cm^3/sec
19	$N_2(B) + Ar \rightarrow N_2(A) + Ar$	4×10^{-15} cm^3/sec

Tabular Data B-1.C-43. Rate coefficients for the Ar - N_2 - NO e-beam pumped system (Concluded).

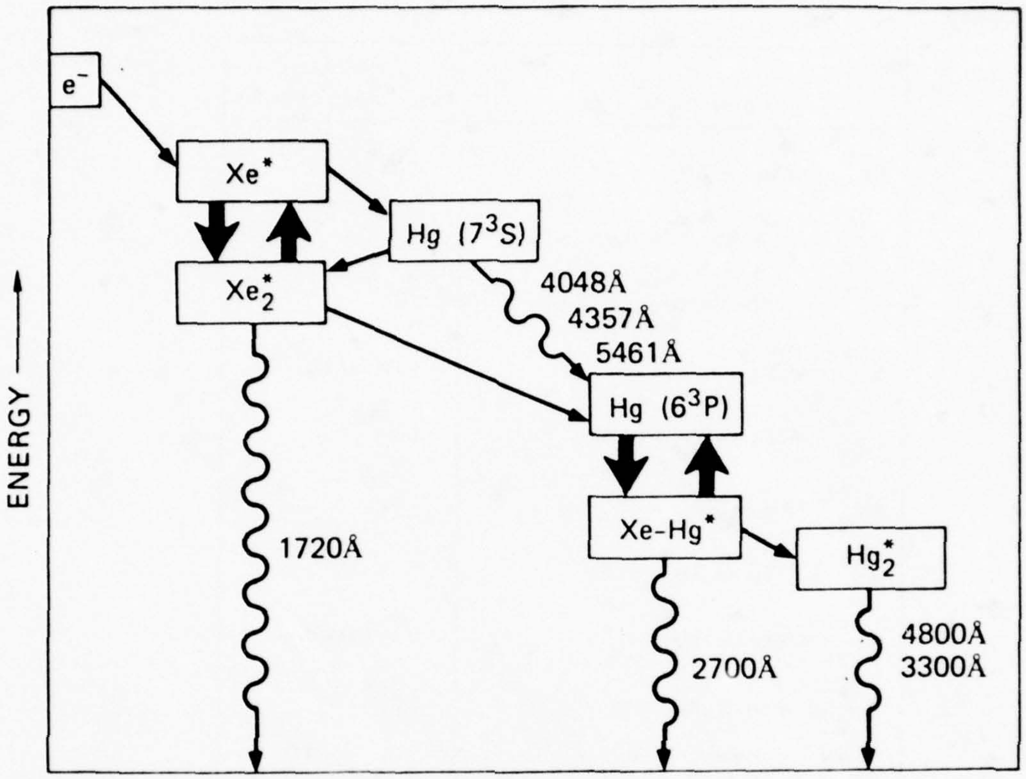
Reaction No.	Reaction	Rate Coefficient
20	$N_2(A)+N_2(A) \rightarrow$ total	1×10^{-10} cm^3/sec
21	" $\rightarrow N_2(E)+N_2$	1×10^{-11} cm^3/sec
22	" $\rightarrow N_2(C)+N_2$	1×10^{-11} cm^3/sec
23	" $\rightarrow N_2(B)+N_2$	8×10^{-11} cm^3/sec
	NO Reactions	
24	$Ar_2^+ + NO \rightarrow NO^+ + 2Ar$	2.4×10^{-10} cm^3/sec
25	$Ar^* + NO \rightarrow$ total	2×10^{-10} cm^3/sec
26	$Ar_2^* + NO \rightarrow$ total	7×10^{-10} cm^3/sec
27	$N_2(B)+NO \rightarrow$ total	7×10^{-11} cm^3/sec
28	$N_2(A)+NO \rightarrow$ total	8×10^{-11} cm^3/sec
28a	$N_2(A)+NO \rightarrow NO(A)+N_2$	4×10^{-11} cm^3/sec
29	$NO(A) \rightarrow NO(X)+h\nu$	4.5×10^{6} s^{-1}
30	$NO(A)+Ar \rightarrow$ total	8×10^{-15} cm^3/sec
31	$NO(A)+NO \rightarrow$ total	2×10^{-10} cm^3/sec

Data taken from R. M. Hill, R. A. Gutchech, D. L. Huestis, D. Mukherjee, and D. C. Lorents.

Tabular Data B-1.C-44. Reactions and rates in pure xenon kinetic model.

Reaction	Rate (cm^3/sec, etc.)
$Xe^+ + 2Xe \rightarrow Xe_2^+ + Xe$	2.5×10^{-31}
$Xe_2^+ + e \rightarrow Xe^{**} + Xe$	2×10^{-7}
$Xe^{**} + 2Xe \rightarrow Xe_2^{**} + Xe$	10^{-31}
$Xe^{**} \rightarrow Xe^* + h\nu$	1.5×10^7
$Xe_2^{**} + Xe \rightarrow Xe^* + 2Xe$	10^{-11}
$Xe_2^{**} + e \rightarrow Xe_2^* + e$	10^{-6}
$Xe^* + 2Xe \rightarrow Xe_2^* + Xe$	5×10^{-32}
$Xe_2^* \rightarrow 2Xe + h\nu$	Variable
$Xe_2^* + e \rightarrow 2\ Xe + e$	10^{-9}
$Xe^{**} + Xe^{**} \rightarrow Xe^+ + Xe + e$	5×10^{-10}
$Xe_2^{**} + Xe_2^{**} \rightarrow Xe_2^+ + 2Xe + e$	5×10^{-10}
$Xe_2^* + Xe_2^* \rightarrow Xe_2^+ + 2Xe + e$	5×10^{-10}
$Xe^* + Xe^* \rightarrow Xe^+ + Xe + e$	5×10^{-10}

Data taken from D. C. Lorents, D. J. Eckstrom, and D. Huestis.

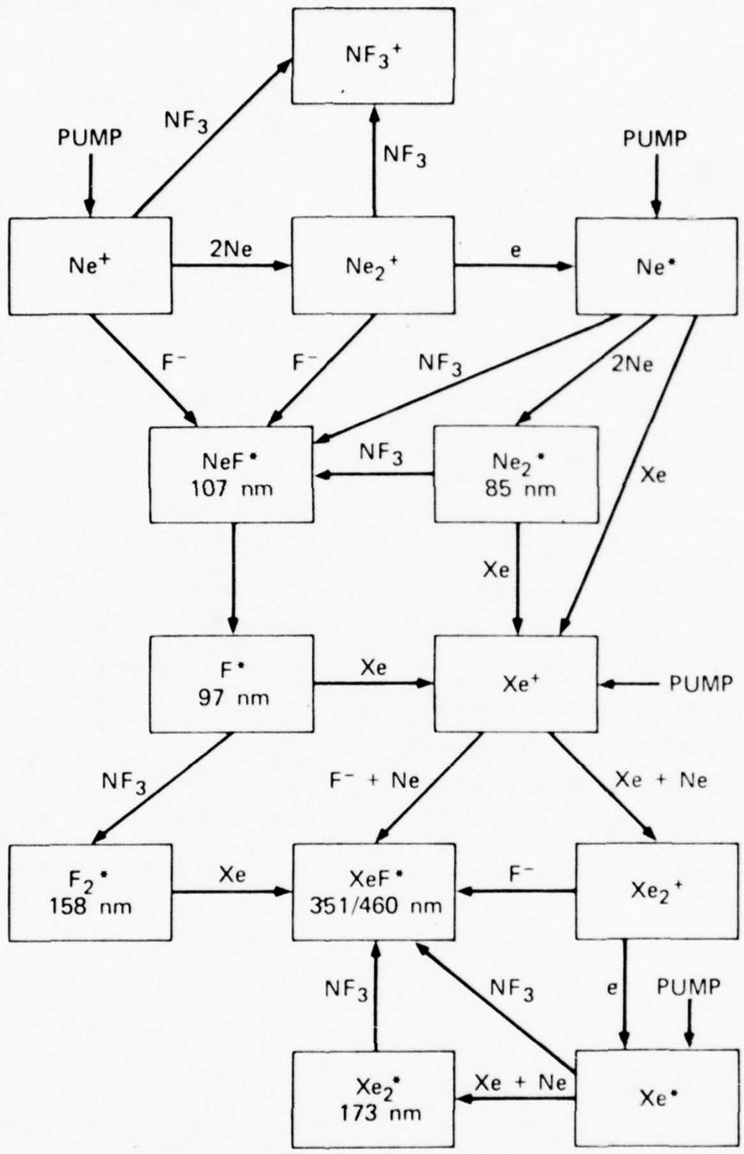


Graphical Data B-1.C-45. Energy flow diagram of the xenon-mercury system.

Tabular Data B-1.C-46. Reactions and rates in xenon-mercury system.

Reaction No.	Reaction		Rate Coefficient
1	$Xe^+ + 2Xe$	$\rightarrow Xe_2^+ + Xe$	2.5×10^{-31} cm^6/sec
2	$Xe_2^+ + e^-$	$\rightarrow Xe^{**} + Xe$	2×10^{-7} cm^3/sec
3	$Xe^{**} + 2Xe$	$\rightarrow Xe_2^{**} + Xe$	10^{-31} cm^6/sec
4	$Xe_2^{**} + Xe$	$\rightarrow Xe^{*} + 2Xe$	10^{-11} cm^3/sec
5	$Xe^{*} + 2Xe$	$\rightarrow Xe_2^{*} + Xe$	5×10^{-32} cm^6/sec
6	Xe_2^{*}	$\rightarrow 2Xe + h\nu$ (1720 Å)	Variable
7	$Xe_2^{*} + e^-$	$\rightleftharpoons Xe^{*} + Xe + e^-$	(a)
8	$Xe^{*} + Hg$	$\rightarrow Xe + Hg\ (7^3S)$	Probably fast (5×10^{-10} cm^3/sec)
9	$Xe^{*} + Hg$	$\rightarrow Xe + Hg\ (6^3P_{0,1,2})$	-
10	$Xe_2^{*} + Hg$	$\rightarrow XeHg^{*} + Xe$	-
11	$Xe_2^{*} + Hg$	$\rightarrow 2Xe + Hg\ (6^3P_{0,1,2})$	Probably fast ($>5 \times 10^{-10}$ cm^3/sec)
12	$2Xe + Hg(7^3S)$	$\rightarrow Xe_2^{*} + Hg$	$> 1.6 \times 10^{-32}$ cm^6/sec
13	$Hg\ (7^3S)$	$\rightarrow Hg\ (6^3P) + h\nu$	1.2×10^8 s^{-1}
14	$Xe + Hg(7^3S)$	$\rightarrow Xe + Hg(6^3P) + h\nu$	fast ($> 10^{-14}$ cm^3/sec)
15	$Xe + Hg(6^3P)$	$\rightarrow Xe + Hg + h\nu$	2.1×10^{-14} cm^3/sec
16	$Xe\text{-}Hg^{*}$	$\rightarrow Xe + Hg + h\nu$	-
17	$Xe\text{-}Hg^{*} + Xe$	$\rightleftharpoons 2Xe + Hg\ (6^3P)$	(a)
18	$Hg(6^3P_0) + Xe$	$\rightleftharpoons Hg\ (6^3P_1) + Xe$	(a)
19	$Xe\text{-}Hg^{*} + Hg$	$\rightarrow Hg_2^{*} + Xe$	Probably fast

[a]Because the equilibrium constants are not known, these rates have not been derived.



Note: Energy input from the electrons comes in along the pump arrows. The specie in each box, plus the component along the reaction arrow, yields the result in the next box. The wavelengths of the emitting species are indicated. They may be subject to quenching by NF_3 or Xe (not shown). NeF^* is presumed to predissociate.

Graphical Data B-1.C-47. Major energy flow pathways in e-beam pumped $Ne/Xe/NF_3$ mixtures.

Tabular Data B-1.C-48. Major input chain reactions in Ne/Xe/NF_3 mixtures.

Reaction	Rate Coefficient (cm^{-3} $molecule^{-1}$ sec^{-1}, etc.)
Fluorine Reactions	
20. $F^* + NF_3 \rightarrow F_2^* + NF_2$	$2.5 \pm 0.1 \times 10^{-10}$
21. $F^* + Xe \rightarrow Xe^+ + F + e$	$3.1 \pm 0.1 \times 10^{-10}$
22. $F^* + 2Ne \rightarrow NeF^* + Ne$	$< 5 \times 10^{-35}$
23. $F^* \rightarrow h\nu$ (97 nm) + F	$\sim 10^4$
	$< 5 \times 10^5$
24. $F_2^* \rightarrow h\nu$ (158 nm) + F_2	2×10^7
25. $F_2^* + Xe \rightarrow XeF^* + F$	$1.3 \pm 0.2 \times 10^{-10}$
26. $F_2^* + NF_3 \rightarrow$ products	$3.8 \pm 0.3 \times 10^{-10}$
Xenon Ion Reactions	
27. $Xe^+ + Xe + Ne \rightarrow Xe_2^+ + Ne$	1.5×10^{-31}
28. $Xe^+ + F^-$ (+ M) $\rightarrow XeF^*$ (+ M)	10^{-6}
29. $Xe_2^+ + e \rightarrow Xe^* + Xe$	2×10^{-7} at 1 eV
30. $Xe_2^+ + F^- \rightarrow XeF^* + Xe$	10^{-6}
Excited Xenon Reactions	
31. $Xe^* + Xe + Ne \rightarrow Xe_2^* + Ne$	$1.6 \pm 0.1 \times 10^{-32}$
32. $Xe^* + NF_3 \rightarrow XeF^* + NF_2$	9×10^{-11}
33a. $Xe_2^* + NF_3 \rightarrow XeF^* + NF_2 + Xe$	5×10^{-11} (33a and 33b)
33b. $Xe_2^* + NF_3 \rightarrow 2Xe + F + NF_2$	
34. $Xe_2^* \rightarrow h\nu$ (173 nm) + 2Xe	10^7-2×10^8

Data Taken from D. L. Huestis, R. M. Hill, D. J. Eckstrom, M. V. McCusker, D. C. Lorents, H. H. Nakano, B. E. Perry, J. A. Mangevicius, and N. E. Schlotter.

Tabular Data B-1.C-48. Major input chain reactions in Ne/Xe/NF_3 mixtures (Concluded).

Reaction	Rate Coefficient (cm^{-3} $molecule^{-1}$ sec^{-1}, etc.)
Neon Ion Reactions	
1. $Ne^{+} + 2Ne \rightarrow Ne_2^{+} + Ne$	4.6×10^{-32}
2. $Ne^{+} + NF_3 \rightarrow NF_3^{+} + Ne$	5×10^{-10}
3. $Ne^{+} + Xe \rightarrow Xe^{+} + Ne$	$< 10^{-14}$
4. $Ne^{+} + F^{-}$ (+ M) $\rightarrow NeF^{*}$ (+ M)	10^{-6}
5. $Ne_2^{+} + e \rightarrow Ne^{*} + Ne$	4×10^{-8} at 1 eV
6. $Ne_2^{+} + NF_3 \rightarrow NF_3^{+} + 2Ne$	5×10^{-10}
7. $Ne_2^{+} + Xe \rightarrow Xe^{+} + 2Ne$	$< 10^{-13}$
8. $Ne_2^{+} + F^{-} \rightarrow NeF^{*} + Ne$	10^{-6}
Excited Neon Reactions	
9. $Ne^{*} + 2Ne \rightarrow Ne_2^{*} + Ne$	5×10^{-34}
	$4.1 \pm 0.4 \times 10^{-34}$
	5.4×10^{-34}
10. $Ne^{*} + NF_3 \rightarrow NeF^{*} + NF_2$	$1.05 \pm 0.05 \times 10^{-10}$
	7.8×10^{-11}
11. $Ne^{*} + Xe \rightarrow Xe^{+} + Ne + e$	7×10^{-11}
	$7.5 \pm 1.0 \times 10^{-11}$
	7.4×10^{-11}
12a. $Ne_2^{*} + NF_3 \rightarrow NeF^{*} + NF_2 + Ne$	5×10^{-11}
12b. $Ne_2^{*} + NF_3 \rightarrow Ne_2F^{*} + NF_2$	
13. $Ne_2^{*} + Xe \rightarrow Xe^{+} + 2Ne + e$	7.5×10^{-11}
14. $Ne_2^{*} \rightarrow h\nu$ (85 nm) + 2Ne	2×10^{5}-3×10^{8}
Neon Fluoride Reactions	
15. $NeF^{*} \rightarrow h\nu$ (107 nm) + Ne + F	4.2×10^{8}
16. $NeF^{*} \rightarrow Ne + F^{*}$	2×10^{9}
17. $NeF^{*} + NF_3 \rightarrow$ products	10^{-10}
18. $NeF^{*} + Xe \rightarrow Xe^{+} + F^{-} + Ne$	10^{-10}
19. $NeF^{*} + 2Ne \rightarrow Ne_2F^{*} + Ne$	10^{-31}

Tabular Data B-1.C-49. Argon/krypton ion chemistry. (Assuming 1500 Torr argon, 50 Torr krypton, and an ion density of approximately 10^{14} cm^{-3}).

	Reaction	Rate	Characteristic Time	Ref.
1	$Ar^+ + 2Ar \rightarrow Ar_2^+ + Ar$	2.3×10^{-31} cm^6/sec	2 ns	A
2	$Ar_2^+ + Kr \rightarrow Kr^+ + 2Ar$	7.5×10^{-10} cm^3/sec	1 ns	B
3	$Ar^+ + Kr \rightarrow Kr^+ + Ar$	$\sim 5\times10^{-11}$ cm^3/sec	13 ns	C
4	$Kr^+ + 2Ar \rightarrow ArKr^+ + Ar$	2.3×10^{-31} cm^6/sec	2 ns	D
5	$Kr^+ + Kr + Ar \rightarrow ArKr^+ + Ar$	2.3×10^{-31} cm^6/sec	67 ns	D
6	$Kr^+ + Kr + Ar \rightarrow Kr_2^+ + Ar$	2.3×10^{-31} cm^6/sec	67 ns	D
7	$Ar_2^+ + Kr \rightarrow ArKr^+ + Ar$	2×10^{-10} cm^6/sec	3 ns	E
8	$ArKr^+ + Kr \rightarrow Kr_2^+ + Ar$	3.2×10^{-10} cm^3/sec	2 ns	B
9	$Ar_2^+ + e \rightarrow Ar^* + Ar$	6.7×10^{-7} cm^3/sec	15 ns	F
10	$ArKr^+ + e \rightarrow Kr^* + Ar$	10^{-6} cm^3/sec (?)	10 ns	G
11	$Kr_2^+ + e \rightarrow Kr^* + Ar$	1.2×10^{-6} cm^3/sec	9 ns	F
12	$Ar^+ + Kr + Ar \rightarrow ArKr^+ + Ar$	2.3×10^{-31} cm^6/sec	67 ns	D

References

A W. F. Liu and D. C. Conway, J. Chem. Phys. 62, 3070 (1975).

B D. K. Bohme, N. G. Adams, M. Moseman, D. B. Dunkin, and E. E. Ferguson, J. Chem. Phys. 52, 5094 (1970).

C Estimate. This is a non-resonant charge transfer and should have a small rate constant.

D Estimate based on the measured value of reference A.

E Estimate based on $Kr_2^+ + Xe$ data of P. Kebarle, R. M. Haynes, and S. K. Searles, J. Chem. Phys. 42, 1684 (1967).

F H. J. Oskam and J. R. Mittelstadt, Phys. Rev. 132, 1445 (1963).

G Estimate based on reference F.

References

1. J. R. Airey, IEEE J. Quantum Electron. QE-3, 208 (1967).

2. J. R. Airey, J. Chem. Phys. 52, 156 (1969).

3. J. R. Airey and I. W. M. Smith, J. Chem. Phys. 57, 1669 (1972).

4. G. Bekefi (Ed.), "Principles of Laser Plasmas," John Wiley and Sons, New York (1976).

5. J. A. Blauer and W. C. Solomon, "Deactivation of Vibrationally Excited Hydrogen Fluoride V-1 and V-2 by Atomic Fluorine," Int. J. Chem. Kinetics 5, 553 (1973).

6. J. A. Blauer, W. C. Solomon, and T. W. Owens, "Vibrational Excitation of Deuterium Fluoride and Hydrogen Fluoride by Atomic and Diatomic Species," Int. J. Chem. Kinetics 4, 293 (1972).

7. M. H. Bortner, A Review of Rate Constants of Selected Reactions of Interest in Reentry Flow Fields in the Atmosphere, National Bureau of Standards Technical Note 484, Washington, D.C. (1969).

8. J. F. Bott, "Gasdynamic Corrections Applied to Laser-Induced Fluorescence Measurements of Hf(v=1) and DF (V=1) Deactivation," SAMSO-TR-74-275, The Aerospace Corporation, El Segundo, California (1975).

9. J. F. Bott and N. Cohen, "Temperature Dependence of V-V and V-R,T Energy Transfer Measurements in Mixtures Containing HF," J. Chem. Phys. 58, 4539 (1973).

10. J. F. Bott and N. Cohen, J. Chem. Phys. 59, 447 (1973).

11. H. C. Brashears, Jr., and D. W. Setser, "Transfer and Quenching Rate Constants for XeF(III,1/2) and XeF(II,3/2)," Appl. Phys. Letts. (in press).

12. B. R. Ronfin and W. O. Jeffers, "The CO Chemical Laser," in R. W. F. Gross and J. F. Bott (Eds.), "Handbook of Chemical Lasers," John Wiley and Sons, New York (1973).

13. M. I. Buchwald and G. J. Wolga, "Vibrational Relaxation of CO_2 (001) by Atoms," J. Chem. Phys. 62, 2828 (1975).

14. K. Bulthuis and G. J. Ponsen, "On the Relaxation of the Lower Laser Level of CO_2," Chem. Phys. Letts. 14, 613 (1972).

15. R. E. Center, J. Chem. Phys. 58, 5230 (1973).

16. R. S. Chan, R. A. McFarlane, and G. J. Wolga, J. Chem. Phys. 56, 667 (1972).

17. H. L. Chen, R. L. Taylor, J. Wilson, P. Lewis, and W. Fyfe, "Atmospheric Pressure Pulsed HF Chemical Laser," J. Chem. Phys. 61, 306 (1974).

18. N. Cohen and J. F. Bott, "A Review of Rate Coefficients in the H_2-Cl_2 Chemical Laser System," SAMSO-TR-75-82, The Aerospace Corporation, El Segundo, California (1975).

19. N. Cohen, "A Brief Review of Rate Coefficients for Reactions in the D_2-F_2 Chemical System," SAMSO-TR-74-14, The Aerospace Corporation, El Segundo, California (1974).

20. N. Cohen and J. F. Bott, "Kinetics of Hydrogen-Halide Chemical Lasers," with 241 references to earlier work in R. W. F. Gross and J. F. Bott (Eds.), "Handbook of Chemical Lasers," John Wiley and Sons, New York, 33 (1973).

21. T. A. Cool, "Transfer Chemical Lasers," in R. W. F. Gross and J. W. Bott (Eds.), "Handbook of Chemical Lasers," John Wiley and Sons, New York, 431 (1973).

22. T. A. Dillon and J. C. Stephenson, J. Chem. Phys. 58, 2056 (1973).

23. T. A. Dillon and J. C. Stephenson, J. Chem. Phys. 58, 3849 (1973).

24. J. A. Dillon and J. C. Stephenson, "Energy Transfer During Orbiting Collisions," J. Chem. Phys. 60, 4286 (1974).

25. N. Djeu, "Intercavity Laser Technique for Population Measurements," (to be published).

26. R. J. Donovan and D. Husain, Ann. Rept. Chem. Soc. London Ser. A 68 (1971).

27. D. H. Douglas-Hamilton and R. S. Lowden, "Carbon Dioxide Electric Discharge Laser Kinetics Handbook," AFWL Technical Report TR-74-216, Avco Everett Research Laboratory, Inc., Everett, Massachusetts (1975).

28. M. G. Dunn and J. A. Lordi, "Measurement of Electron Temperature and Number Density in Shock-Tunnel Flows, Part II: $NO^+ + e^-$ Dissociative Recombination Rate in Air," AIAA J. 11, 2099 (1969).

29. G. Emanuel and W. D. Adams, "RESALE-2, CO_2 and INHALE," Technical Report TR-0172(2776)-5, The Aerospace Corporation, El Segundo, California (1972).

30. F. C. Fehsenfeld and E. E. Ferguson, "Laboratory Studies of Negative Ion Reactions with Atmospheric Trace Constituents," J. Chem. Phys. 61, 3181 (1974).

31. D. L. Albritton, Atomic Data and Nuclear Data Tables 22, 1-101 (1978).

32. J. W. Gallagher, "Energy Transfer Collisions of Atoms and Molecules," Joint Institute for Laboratory Astrophysics, NBS Newsletter, No. 8 (1979).

33. D. Garvin and D. F. Hampson (Eds.), "Chemical Kinetics Data Survey VII — Tables of Rate and Photochemical Data for Modeling of the Stratoshpere (Revised)," NBS IR 74-430, Washington, D.C. (1974).

34. K. R. German, "Collision and Quenching Cross Sections in the $A^2\Sigma^+$ State of OH and OD," J. Chem. Phys. 64, 4065 (1976).

35. F. R. Gilmore, E. Bauer, and J. W. McGowan, "A Review of Atomic and Molecular Excitation Mechanisms in Nonequilibrium Gases Up to 20,000°K," J. Quant. Spectrosc. Radiat. Trans., 9, 157 (1969).

36. M. C. Gower and A. I. Carswell, "Vibration-Translation Rates in CO_2 Glow Discharges," Appl. Phys. Letts. 22, 321 (1973).

37. W. H. Green and J. K. Hancock, J. Chem. Phys. 59, 4326 (1973).

38. R. W. F. Gross and J. F. Bott (Eds.), "Handbook of Chemical Lasers," John Wiley and Sons, New York (1973).

39. R. A. Gutcheck, R. M. Hill, D. L. Huestis, D. C. Lorents, and M. V. McCusker, "Studies of E-Beam Pumped Molecular Lasers," Technical Report SRI No. MP 75-43, Stanford Research Institute, Menlo Park, California (1975).

40. G. Hancock, C. Morley, and I. W. M. Smith, Chem. Phys. Letts. 12, 193 (1971).

41. G. Hancock and I. W. M. Smith, Appl. Opt. 10, 1827 (1971).

42. C. F. Hansen "Temperature Dependence of NO^+ + e-Dissociative Recombination Rate Coefficient," Phys. Fluids 11, 904 (1968).

43. R. F. Heidner and J. F. Bott, "Vibrational Deactivation of HF(v=1) and DF(v=1) by H and D Atoms," Technical Report SAMSO-TR-75-80, The Aerospace Corporation, El Segundo, California (1975).

44. W. L. Hendricks, J. Thoenoes, A. J. McDanal, and R. R. Mikatarian, "Laser and Mixing Program (LAMP) Theory and User's Guide," MICOM Technical Report RH-CR-77-4, Lockheed Missiles and Space Company, Huntsville, Alabama (1976).

45. R. M. Hill, R. A. Gutcheck, D. L. Huestis, D. Mukherjee, and D. C. Lorents, "Studies of E-Beam Pumped Molecular Lasers," Technical Report SRI No. MP 74-39, Stanford Research Institute, Menlo Park, California (1974).

46. K. Hohla and K. L. Kompa, "The Photochemical Iodine Laser," in R. W. F. Gross and J. F. Bott (Eds.), "Handbook of Chemical Lasers," John Wiley and Sons, New York, 667 (1973).

47. D. W. Howgate and T. A. Barr, Jr., J. Chem. Phys. 59, 2815 (1973).

48. D. L. Huestis, R. M. Hill, H. H. Nakano, and D. C. Lorents, "Quenching of Ne*, F*, and F_2^* in Ne/Xe/NF_3 and Ne/Xe/F_2 Mixtures," J. Chem. Phys. 69, (11), 5133, (1978).

49. D. L. Huestis, R. M. Hill, D. J. Eckstrom, M. V. McCusker, D. C. Lorents, H. H. Nakano, B. E. Perry, J. A. Margevicius, and N. E. Scholtter, "New Electronic Transition Laser Systems," Technical Report SRI No. 78-07, Stanford Research Institute, Menlo Park, California (1978).

50. R. E. Huie and J. T. Herron, "The Rate Constant for the Reaction $O_3 + NO_2 \rightarrow O_2 + NO_3$ Over the Temperature Range 259-362°K," Chem. Phys. Letts. 27, 411 (1974).

51. E. C. Y. Inn, "Rate of Recombination of Oxygen Atoms and CO at Temperatures Below Ambient," J. Chem. Phys. 61, 1589 (1974).

52. J. H. Jacob, M. Rokni, J. A. Mangano, and R. Brochu, "Formation and Quenching Processes in E-Beam-Pumped Kr/F_2 Mixtures," Appl. Phys. Letts. 32, 109 (1978).

53. R. Johnsen, H. L. Brown, M. A. Biondi, "Ion-Molecule Reactions Involving N^+_2, N^+, O^+_2 and O^+ Ions from 300°K to $\sim$ 1 eV," J. Chem. Phys. 52, 5080 (1970).

54. S. J. Kast and C. Cason, "Performance Comparison of Pulsed Discharge and E-Beam Controlled CO_2 Lasers," J. Appl. Phys. 44, (1631) (1973).

55. R. L. Kerber, N. Cohen, and G. Emanuel, "A Kinetic Model and Computer Simulation for a Pulsed DF-CO_2 Chemical Transfer Laser," IEEE J., Quant. Elect. QE-9, 94 (1973).

56. J. H. Kolts and D. W. Setser, "Decay Rates of Ar(4s, $^3P_2$), Ar(4s, $^3P_0$), Kr(5s, $^3P_2$), and Xe(6s, $^3P_2$) Atoms in Argon," J. Chem. Phys. 68, (11) 4848 (1978).

57. S. C. Kurzius, "LAMP Reaction Models For Analysis of Chemical Lasers," MICOM Technical Report -CR-75-31, Lockheed Missiles and Space Company, Huntsville, Alabama (1975).

58. S. C. Kurzius, "HF/DF Chemical Laser Performance Modification by Chemical Additives," MICOM Technical Report RK-CR-75-3, Lockheed Missiles and Space Company, Huntsville, Alabama (1974).

59. M. A. Kwok and N. Cohen, "Flow Tube Studies of the Deactivation of HF(v) by Selected Polyatomic Molecules," J. Chem. Phys. 61, 5221 (1974).

60. R. D. Levine and J. Jortner (Eds.), "Molecular Energy Transfer," John Wiley and Sons, New York (1976).

61. P. F. Lewis and D. W. Trainor, "Survey of Vibrational Relaxation Data for O_2, N_2, NO, H_2, CO, HF, HCℓ, CO_2, and H_2O" ARPA Report No. AMP422, Avco, Everett, Massachusetts (1974).

62. D. C. Lorents, D. J. Eckstrom, and D. Huestis, "Excimer Formation and Decay Processes in Rare Gases," Technical Report SRI No. MP 73-2, Stanford Research Institute, Menlo Park, California (1973).

63. R. A. Lucht and T. A. Cool, J. Chem. Phys. 60, 1026 (1974).

64. A. Mandl and J. J. Ewing, "Device for Optically Exciting XeF^* and Other Rare-Gas Excited Complexes," Rev. Sci. Insturm. 48, 1434 (1977).

65. A. Mandl and J. H. Parks, "Collisional Quenching Kinetics for the HgCℓ* (B 1/2) State," Appl. Phys. Letts. 33, 498 (1978).

66. J. A. Mangano, J. H. Jacob, M. Rokni, and A. Hawryluk, "Three-Body Quenching of KrF* By Ar and Broad-Band Emission at 415-mm," Appl. Phys. Letts. 37, 326 (1971).

67. S. W. Mayer and N. Cohen, "Rate Coefficients Calculated by the Bond-Energy Bond-Order Method for Excited State F + $H_2 \rightleftarrows$ H + Hf Reactions," Report SAMSO-TR-79-18, Space and Missile System Organization, Air Force Systems Command, Los Angeles, California (1979).

68. E. W. McDaniel, V. Čermák, A. Dalgarno, E. E. Furguson, and L. Friedman, Ion-Molecule Reactions, Wiley-Interscience, New York (1970).

69. M. McFarland, D. L. Albritton, F. C. Fehsenfeld, E. E. Ferguson, and A. L. Schmeltekopf, "Flow-Drift Technique for Ion Mobility and Ion-Molecule Reaction Rate Constant Measurements. III. Negative Ion-Reactions of O^- with CO, NO, H_2 and D," J. Chem. Phys. 59, 6629 (1973).

70. R. C. Millikan, J. Chem. Phys. 38, 2855 (1963).

71. R. K. Mitchum, J. P. Freeman, and G. G. Meisels, "Arrival Time Distribution in High Pressure Mass Spectrometry, VI, Formation and Reaction of Negative Ions in Carbon Dioxide," J. Chem. Phys. 62, 2464 (1975).

72. C. B. Moore, IEEE J. Quantum Electron. QE-4, 52 (1968).

73. C. B. Moore, R. W. Wood, B. Lok Hu, and J. T. Yardley, "Vibrational Energy Transfer in CO_2 Lasers," J. Chem. Phys. 46, 4222 (1967).

74. W. L. Nighan "Electron Energy Distributions and Collision Rates in Electrically Excited N_2, CO and CO_2," Phys. Rev. A. 2, 1989 (1970).

75. W. L. Nighan and W. J. Wiegand, "Influence of Negative-Ion Processes on Steady-State Properties and Striations in Molecular Gas Discharges," Phys. Rev. A 10, 922 (1974).

76. H. Okabe, J. Chem. Phys. 56, 4381 (1972).

77. J. H. Parker and G. C. Pimentel, J. Chem. Phys. 51, 91 (1969).

78. H. T. Powell, J. Chem. Phys. 59, 4937 (1973).

79. H. T. Powell and J. D. Kelley, J. Chem. Phys. 60, 2191 (1974).

80. A. W. Ratliff, S. C. Kurzius, A. J. McDanal, and R. R. Mikatarian, "Analysis of Chemical Lasers," MICOM Technical Report RK-CR-75-31, I, Lockheed Missiles and Space Company, Huntsville, Alabama (1975).

81. M. Rokni, J. A. Mangano, J. H. Jacob, and J. C. Hsia, "Rare-Gas Fluoride Lasers," IEEE J. Quantum Electron. QE-14, (7), 468 (1978).

82. M. Rokni, J. H. Jacob, J. A. Mangano, and R. Brochu, "Two-and Three-Body Quenching of XeF* By Ar and Xe," Appl. Phys. Letts. 30, 458 (1977).

83. M. Rokin, J. A. Jacob, J. A. Mangano, and R. Brochu, "Formation and Quenching of XeF* in Ne/Xe/F_2 Mixtures," Appl. Phys. Letts. 32, 223 (1978).

84. M. Rokni, J. H. Jacob, J. A. Mangano, and R. Brochu, "Formation and Quenching Kinetics of ArF," Appl. Phys. Letts. 31, 79 (1977).

85. M. Rokni, J. A. Jacob, and J. A. Mangano, "Dominant Formation and Quenching Processes in E-Beam Pumped ArF* and KrF* Lasers," Phys. Rev. 16, 2216 (1977).

86. W. A. Rosser, A. D. Sharma, and E. T. Gerry, "Deactivation of Vibrationally Excited Carbon Dioxide (001) by Collisions with Carbon Monoxide," J. Chem. Phys. 54, 1196 (1971).

87. W. A. Rosser, A. D. Wood, and E. T. Gerry, "Deactivation of Vibrationally Excited Carbon Dioxide (ν_3) by Collisions with Carbon Dioxide or with Nitrogen," J. Chem. Phys. 50, 4996 (1969).

88. W. A. Rosser, Jr. and E. T. Gerry, "De-Excitation of Vibrationally Excited CO_2* (ν_3) by Collisions with He, O_2, and H_2O," J. Chem. Phys. 53, 2286 (1969).

89. J. R. Rumble, Jr., and J. W. Gallagher, "Energy Transfer Collisions of Atoms and Molecules," Joint Institute for Laboratory Astrophysics, NBS Newsletter, No. 7, (1978).

90. Y. Sato and S. Tsuchiya, "Shock-Tube Study of Vibrational Energy Transfers in the CO_2-CO Systems," J. Phys. Soc., Japan 33, 1120 (1972).

91. Y. Sato, S. Tsuchiya, and K. Kuratani, "Shock-Wave Study of Vibrational Energy Exchange Between Diatomic Molecules," J. Chem. Phys. 50, 1911 (1969).

92. V. H. Shui, Calculation of Recombination Rate Constants for KrF + R + R $\rightarrow$ RKrF + R (R = Ar, Kr)," Appl. Phys. Letts. 31, 50 (1977).

93. R. Simonaitis and J. Heicklen, "Kinetics and Mechanism of the Reaction of O (^3P) with CO," J. Chem. Phys. 56, 2004 (1972).

94. T. G. Slanger, B. J. Wood, and G. Black, "Investigation of the Rate Coefficient for O (^3P) + $NO_2 \rightarrow O_2$ + NO," Int. J. Chem. Kinetics 5, 615 (1973).

95. T. G. Slanger, B. J. Wood, and G. Black, "Kinetics of O (^3P) + CO + M Recombination," J. Chem. Phys. 57, 233 (1972).

96. D. J. Smith, D. W. Setser, K. C. Kim, and D. J. Bogan, "HF Infrared Chemiluminescence. Relative Rate Constants for Hydrogen Abstraction From Hydrocarbons, Substituted Methanes, and Inorganic Hydrides," J. Chem. Phys. 81, (9), 898 (1977).

97. I. W. M. Smith and C. Wittig, Trans. Faraday Soc. 69, 939 (1973).

98. D. F. Starr, J. K. Hancock, and W. H. Green, "Vibrational Deactivation of Carbon Monoxide by Hydrogen and Nitrogen from 100 to 650°K," J. Chem. Phys. 61, 5421 (1974).

99. R. R. Stephens and T. A. Cool, J. Chem. Phys. 56, 5683 (1972).

100. J. C. Stephenson, J. Finzi, and C. B. More, J. Chem. Phys. 56, 5214 (1972).

101. D. R. Stull and H. Prophet, Jannaf Tables of Themochemical Data, Natl. Stand. Ref. Data Sec. 37 (1972).

102. J. H. Sullivan, R. C. Feber, and J. W. Starner, "Mechanisms and Types of Explosive Behavior in Hydrogen-Fluorine Systems," J. Chem. Phys., 62, 1714 (1975).

103. E. A. Sutton "Chemistry of Electrons in Pure-Air Hypersonic Wakes," AIAA J. 6, 1873 (1968).

104. K. Tamagake and D. W. Setser, "Simulation of the Bound-Free KrF* Emission Spectra from Reactive Quenching of Kr(5s[3/2]$_2$) and Kr (5s[3/2]$_1$) Atoms," J. Chem. Phys. 67, (10) 4370 (1977).

105. R. L. Taylor and S. Bitterman, "Survey of Vibrational Relaxation Data for Processes Important in the CO_2-N_2 Laser System." Rev. Mod. Phys. 41, 26 (1969).

106. J. Thoenes and S. C. Kurzius, "Plasma Chemistry Processes in Pulsed Electric Discharge Lasers," MICOM Technical Report RH-CR-76-12, Lockheed Missiles and Space Company, Huntsville, Alabama (1976).

107. J. Thoenes and S. C. Kurzius, "EDC Performance Model Part III - Analyses of Closed Cycle Electron-Beam Sustained CO_2 EDL with Air Contaminant," MICOM Technical Report RG-CR-75-2, Lockheed Missiles and Space Company, Huntsville, Alabama (1976).

108. J. Thoenes, S. C. Kurzius, and M. L. Pearson, "EDL Performance Model Part I - Theory and User's Guide," MICOM Technical Report RG-CR-75-2, Lockheed Missiles and Space Company, Huntsville, Alabama (1975).

109. S. Tsuchiya, N. Nielsen, and S. H. Bauer, J. Phys. Chem. 77, 2455 (1973).

110. C. Turner and N. L. Rapagnani, "Laser Fusion Program - Semiannual Report, "UCRL-50021-73-1, Lawrence Livermore Laboratory, California, UCID-16935 (January-June 1973).

111. J. E. Velazco, J. H. Kolts, and D. W. Setser "Quenching Rate Constants for Metastable Ar, Kr, and Xe Atoms by Flourine Containing Molecules and Branching Ratios for XeF* and KrF* Formation," J. Chem. Phys. 65, (9), 3468 (1976).

112. J. F. Velazco, J. H. Kolts, and D. W. Setser, "Rate Constants and Quenching Mechanisms for the Metastable States of Ar, Kr, and Xe," J. Chem. Phys. (in press).

113. R. T. Watson "Chemical Kinetics Data Survey VIII - Rate Constants of $C\ell O_x$ of Atmosphere Interest," NBS IR 74-516, Washington, D.C. (1974).

114. W. J. Wiegand and W. L. Nighan, "Plasma Chemistry of CO_2-N_2-He Discharges," Appl. Phys. Letts. 22, 583 (1973).

115. R. L. Wilkins "Monte Carlo Calculations of Reaction Rates and Energy Distributions Among Reactions Products. IV. F + HF(v) → HF(v') + F and F + DF(v) → DF(v') + F," J. Chem. Phys. 49, 698 (1973).

116. R. L. Wilkins "Monte Carlo Calculations of Reaction Rates and Energy Distribution Among Reaction Products: Reactions of HF and DF with H- and D-Atoms," SAMSO-TR-74-94, The Aerospace Corporation, El Segundo, California (1974).

117. D. Williams et al., Mol. Phys. 20, 769 (1971).

Section B-1.D. ION-NEUTRAL AND NEUTRAL-NEUTRAL COLLISIONS INVOLVING NOBLE GAS AND HALOGEN STRUCTURES

CONTENTS

General References:

1. C. H. Chen, J. B. Judish and M. G. Payne, J. Phys. B. 11, 2189 (1978).

2. J. H. Kolts and D. W. Setser, J. Chem. Phys. 68, 4848 (1978).

3. J. E. Velazco, J. H. Kolts, and D. W. Setser, J. Chem. Phys. 69, 4357 (1978).

Data Needed: In general, there still exists a lack of knowledge concerning the excitation state of reaction products.

Explanation of Table

The data presented in the following table and its associated graphs have been taken for the most part from data reported in 1977 and 1978. This data table constitutes an update and continuation of Section B-I (Vol. I) of Technical Report H-78-1 ("Compilation of Data Relevant to Rare Gas-Rare Gas and Rare Gas-Monohalide Excimer Lasers," US Army Missile Command, Redstone Arsenal, Alabama, December 1977). This table contains data for both two- and three-body reactions. The general ordering of the reactions is two-body noble-noble, three-body noble-noble, two-body noble-halogen, three-body noble-halogen, two-body halogen-halogen, and three-body halogen-halogen. Both noble gases and halogens are listed in order from least massive to most massive.

The energy range covered in this table is from thermal to approximately 10 eV, with a few exceptions where graphical data were available both below and above 10 eV and there was no reason not to present the entire graph. In some cases the temperature at which a reaction rate was measured was not found in the reference, but the temperature was assumed to be 300°K. In these cases, the superscript "a" appears to the right of the reaction temperature. Toward the right side of this table, there is a list of cross sections, reaction rates, or (if data are available over an extended energy range) a graph number. These graphs can be found immediately following this table.

Reaction			Temperature, Velocity or Energy	Cross Section or Reaction Rate	Reference
		Atomic Noble-Atomic Noble Reactants			
$He^* + He^*$	$\rightarrow$	total ionization	.01 - 10eV	Graph 1	1
$He^{2+} + He$	$\rightarrow$	$He^+ + He^+$	300^oK	$4.8 \pm 0.5 \times 10^{-14} cm^3/s$	2
$He^* + Ne^*$	$\rightarrow$	$HeNe^+ + e^-$	0.01 - 10eV	Graph 2	3
$He^* + Ne^*$	$\rightarrow$	$He + Ne^+ + e^-$	0.01 - 10eV	Graph 2	3
$He^+(^2S) + Ne$	$\rightarrow$	$He + Ne^+$	300^oK	$1 \pm 0.5 \times 10^{-15} cm^3/s$	2
$He^{2+} + Ne$	$\rightarrow$	He^+	0.1 - 30eV	Graph 3	4
$He^*(2^1S) + Ar$	$\rightarrow$	quenching	300^oK	$2 \times 10^{-10} cm^3/s$	5
$He^*(2^1S) + Ar$	$\rightarrow$	total ionization	$1-3 \times 10^3 m/s$	Graph 4	6
$He^*(2^3S) + Ar$	$\rightarrow$	total ionization	$1-3 \times 10^3 m/s$	Graph 4	6
$He^+ + Ar$	$\rightarrow$	$Ar^+ + He$	8 - 60eV	Graph 5	7
$He^*(2^1S) + Kr$	$\rightarrow$	quenching	300^oK	$3.8 \times 10^{-10} cm^3/s$	5
$He^*(2^1S) + Kr$	$\rightarrow$	total ionization	$1-3 \times 10^3 m/s$	Graph 6	6
$He^*(2^3S) + Kr$	$\rightarrow$	total ionization	$1-3 \times 10^3 m/s$	Graph 6	6
$He^+ + Kr$	$\rightarrow$	$Kr^+ + He$	5 - 60eV	Graph 5	7
$He^*(2^1S) + Xe$	$\rightarrow$	quenching	300^oK	$4.8 \times 10^{-10} cm^3/s$	5

Reaction			Temperature, Velocity or Energy	Cross Section or Reaction Rate	Reference
$He^*(2^1S) + Xe$	$\rightarrow$	total ionization	$1\text{-}3 \times 10^3$ m/s	Graph 7	6
$He^*(2^3S) + Xe$	$\rightarrow$	total ionization	$1\text{-}3 \times 10^3$ m/s	Graph 7	6
$He^+ + Xe$	$\rightarrow$	$Xe^+ + He$	2 - 60eV	Graph 5	7
$Ne^{2+} + He$	$\rightarrow$	$Ne^+ + He^+$	$300^\circ K$	$5.5 \pm 1 \times 10^{-15}\ cm^3/s$	2
$Ne^{2+} + He$	$\rightarrow$	He^+	3 - 6eV	$\leq 2.0 \times 10^{-2}\ \mathring{A}^2$	4
$Ne^{2+}(^1S) + Ne$	$\rightarrow$	$Ne^+ + Ne^+$	$300^\circ K$	$2.7 \pm 0.3 \times 10^{-14}\ cm^3/s$	2
$Ne^{2+}(^3P) + Ne$	$\rightarrow$	$Ne^+ + Ne^+$	$300^\circ K$	$2.1 \pm 0.2 \times 10^{-14}\ cm^3/s$	2
$Ne^{2+}(^1D) + Ne$	$\rightarrow$	$Ne^+ + Ne^+$	$300^\circ K$	$1.9 \pm 0.2 \times 10^{-14}\ cm^3/s$	2
$Ne^{2+} + Ne$	$\rightarrow$	Ne^+	8eV	$\leq 1.5 \times 10^{-2}\ \mathring{A}^2$	4
$Ne^+(^2P) + Ar$	$\rightarrow$	$Ne + Ar^+$	$300^\circ K$	$6 \pm 1 \times 10^{-15}\ cm^3/s$	2
$Ne^{2+} + Ar$	$\rightarrow$	Ne^+	0.1 - 24eV	Graph 8	4
$Ne^+ + Kr$	$\rightarrow$	$Kr^+ + Ne$	9 - 60eV	Graph 5	7
$Ne^+ + Xe$	$\rightarrow$	$Xe^+ + Ne$	3 - 60eV	Graph 5	7
$Ar^{2+}(^1S) + He$	$\rightarrow$	$Ar^+ + He^+$	$300^\circ K$	$< 10^{-14}\ cm^3/s$	2
$Ar^{2+}(^3P) + He$	$\rightarrow$	$Ar^+ + He^+$	$300^\circ K$	$7 \pm 3 \times 10^{-11}\ cm^3/s$	2

Reaction			Temperature, Velocity or Energy	Cross Section or Reaction Rate	Reference
$Ar^{2+}(^1D) + He$	$\rightarrow$	$Ar^+ + He^+$	300^oK	$\sim 2\times10^{-10}cm^3/s$	2
$Ar^{2+} + He$	$\rightarrow$	Ar^+	0.1 - 10eV	Graph 9	4
$Ar^{3+} + He$	$\rightarrow$	Ar^{2+}	0.1 - 6eV	Graph 9	4
$Ar^{2+} + Ne$	$\rightarrow$	Ar^+	0.1 - 20eV	Graph 3	4
$Ar(^3P_o) + Ar$	$\rightarrow$	decay rate	300^oK	$5.3\pm0.9\times10^{-15}cm^3/s$	8
$Ar(^3P_2) + Ar$	$\rightarrow$	decay rate	300^oK	$2.1\pm0.3\times10^{-15}cm^3/s$	8
Ar^* 4p $[1/2]_1$ + Ar	$\rightarrow$	deactivation	300^oK	$2.0\pm0.6\times10^{-11}cm^3/s$	9
Ar^* 4p'$[1/2]_1$ + Ar	$\rightarrow$	deactivation	300^oK	$5.3\pm0.6\times10^{-11}cm^3/s$	9
Ar^* 4p$[3/2]_1$ + Ar	$\rightarrow$	deactivation	300^oK	$7.7\pm0.8\times10^{-11}cm^3/s$	9
Ar^* 4p$[3/2]_2$ + Ar	$\rightarrow$	deactivation	300^oK	$\leq 1.8\times10^{-11}cm^3/s$	9
Ar^* 4p'$[3/2]_1$ + Ar	$\rightarrow$	deactivation	300^oK	$5.6\pm1.1\times10^{-11}cm^3/s$	9
Ar^* 4p'$[3/2]_2$ + Ar	$\rightarrow$	deactivation	300^oK	$1.1\pm0.12\times10^{-10}cm^3/s$	9
Ar^* 4p$[5/2]_2$ + Ar	$\rightarrow$	deactivation	300^oK	$4.7\pm0.7\times10^{-11}cm^3/s$	9
Ar^* 4p$[5/2]_3$ + Ar	$\rightarrow$	deactivation	300^oK	$5.9\pm0.4\times10^{-11}cm^3/s$	9
$Ar^{2+}(^1S) + Ar$	$\rightarrow$	$Ar^+ + Ar^+$	300^oK	$6.0\pm2\times10^{-12}cm^3/s$	2

Reaction			Temperature, Velocity or Energy	Cross Section or Reaction Rate	Reference
$Ar^{2+}(^3P) + Ar$	→	$Ar^+ + Ar^+$	300^oK	$3.7 \pm 0.4 \times 10^{-14} cm^3/s$	2
$Ar^{2+}(^1D) + Ar$	→	$Ar^+ + Ar^+$	300^oK	$10^{-12} cm^3/s$	2
$Ar^{2+} + Ar$	→	Ar^+	0.2 - 32eV	Graph 8	4
$Ar(^1P_1) + Kr$	→	quenching	300^oK	$1.2 \times 10^{-12} cm^3/s$	11
$Ar(^3P_1) + Kr$	→	quenching	300^oK	$9.1 \times 10^{-12} cm^3/s$	11
$Ar(^3P_2) + Kr$	→	quenching	300^oK	$6 \times 10^{-12} cm^3/s$	10
$Ar^+ + Kr$	→	$Kr^+ + Ar$	9 - 20eV	Graph 5,10	7
$Ar^{2+} + Kr$	→	Ar^+	0.1 - 40eV	$1.1\ \mathring{A}^2$	4
$Ar(^1P_1) + Xe$	→	quenching	300^oK	$3.3 \times 10^{-10} cm^3/s$	11
$Ar(^3P_o) + Xe$	→	quenching	300^oK	$3.0 \times 10^{-10} cm^3/s$	10
$Ar(^3P_1) + Xe$	→	quenching	300^oK	$2.2 \times 10^{-10} cm^3/s$	11
$Ar(^3P_2) + Xe$	→	quenching	300^oK	$1.8 \times 10^{-10} cm^3/s$	10
$Ar^+ + Xe$	→	$Xe^+ + Ar$	6 - 20eV	Graph 5,10	7
$Kr^*(^3P_2) + He$	→	depolarization	300^oK	$10 \pm 1\ \mathring{A}^2$	12
$Kr(^3P_2) + Ar$	→	decay rate	300^oK	$6.9 \pm 0.6 \times 10^{-16} cm^3/s$	8

Reaction			Temperature, Velocity or Energy	Cross Section or Reaction Rate	Reference
$Kr^{*}(^{3}P_{2}) + Kr$	→	total disorientation	$300^{o}K$	$120 \pm 7\ \mathring{A}^{2}$	12
$Kr^{2+} + Kr$	→	$Kr^{+} + Kr^{+}$	$300^{o}K$	$4.8 \times 10^{-14} cm^{3}/s$	2
$Kr(^{3}P_{2}) + Xe$	→	quenching	$300^{o}K$	$1.6 \times 10^{-10} cm^{3}/s$	10
$Kr^{+} + Xe$	→	$Xe^{+} + Kr$	8 - 40eV	Graph 5	7
$Xe(^{3}P_{2}) + Ar$	→	decay rate	$300^{o}K$	$5.0 \pm 0.7 \times 10^{-16} cm^{3}/s$	8
$Xe(^{3}P_{2}) + Xe$	→	decay rate	$300^{o}K$	$3.7 \pm 0.4 \times 10^{-15} cm^{3}/s$	8
$Xe^{*}(^{3}P_{2}) + Xe$	→	total disorientation	$300^{o}K$	$155 \pm 7\ \mathring{A}^{2}$	12
$Xe^{*}(^{3}P_{2}) + Xe$	→	disorientation without exchange	$300^{o}K$	$95 \pm 35\ \mathring{A}^{2}$	12
$Xe^{*}(^{3}P_{2}) + Xe$	→	disalignment without exchange	$300^{o}K$	$150 \pm 40\ \mathring{A}^{2}$	12
$^{129}Xe^{*}(^{3}P_{2}) + {}^{132}Xe$	→	$^{132}Xe^{*}(^{3}P_{2}) + {}^{129}Xe$	$300^{o}K$	$70 \pm 30\ \mathring{A}^{2}$	12
$Xe^{2+} + Xe$	→	$Xe^{+} + Xe^{+}$	$300^{o}K$	$3.2 \pm 0.3 cm^{3}/s$	2
		Diatomic Noble-Noble Reactants			
$He_{2}(2^{3}\Sigma) + He(2^{3}S)$	→	quenching	$300^{o}K^{a}$	$2.5 \times 10^{-9} cm^{3}/s$	13
$He_{2}(2^{3}\Sigma) + He_{2}(2^{3}\Sigma)$	→	quenching	$300^{o}K^{a}$	$1.3 \times 10^{-10} cm^{3}/s$	14

Reaction			Temperature, Velocity or Energy	Cross Section or Reaction Rate	Reference
$He_2(2^3\Sigma_u^+) + Ne$	$\rightarrow$	Ne^*	300^oK	$2.1\pm0.6\times10^{-10}cm^3/s$	14
$He_2^+ + Ne$	$\rightarrow$	$2He + Ne^+$	300^oK	$1.4\times10^{-10}cm^3/s$	15
$He_2(^3\Sigma_u) + Ar$	$\rightarrow$	excitation transfer	300^oK	3.1×10^{-10}	16
$He_2(2^3\Sigma_u^+) + Ar$	$\rightarrow$	ionization	300^oK	$1.5\pm0.3\times10^{-10}cm^3/s$	17
$Ne_2^+ + Kr$	$\rightarrow$	$NeKr^+ + Ne$	0.04 - 0.1eV(lab)	$\leq 10^{-13}cm^3/s$	18
$Ne_2^+ + Xe$	$\rightarrow$	$NeXe^+ + Ne$	0.04 - 0.1eV(lab)	$\leq 10^{-13}cm^3/s$	18
$Ar_2^*(1_u) + Kr$	$\rightarrow$	quenching	300^oK^a	$9.1\times10^{-12}cm^3/s$	11
$Ar_2^*(0_u) + Xe$	$\rightarrow$	quenching	300^oK^a	$2.4\times10^{-10}cm^3/s$	11
$Ar_2^*(1_u) + Xe$	$\rightarrow$	quenching	300^oK^a	$2.2\times10^{-10}cm^3/s$	11
$Kr_2^*(0_u^+) + Kr$	$\rightarrow$	$Kr_2^*(^1\Sigma_u^+, {}^3\Sigma_u^+) + Kr$	300^oK	$10^{-10}cm^3/s$	19
$Xe_2^*(0_u^+) + Xe$	$\rightarrow$	$Xe_2^*(^1\Sigma_u^+, {}^3\Sigma_u^+) + Xe$	300^oK	$8.7\times10^{-11}cm^3/s$	19
Atomic Noble-Noble-Noble Reactants					
$He^{2+} + He + He$	$\rightarrow$	$He^+ + He^+ + He$	300^oK	$2.0\pm1\times10^{-31}cm^6/s$	2
$Ne^{2+} + He + Ne$	$\rightarrow$	$Ne^+ + He^+ + Ne$	300^oK	$2.0\pm0.5\times10^{-31}cm^6/s$	2

Reaction			Temperature, Velocity or Energy	Cross Section or Reaction Rate	Reference
$Ne^{+}(^{2}P) + Ar + Ar$	$\rightarrow$	$Ne + Ar^{+} + Ar$	$300^{o}K$	$5 \pm 2 \times 10^{-32}$	2
$Ar(^{3}P_{o}) + 2Ar$	$\rightarrow$	decay rate	$300^{o}K$	$8.3 \pm 10^{-33} cm^{6}/s$	8
$Ar(^{3}P_{2}) + 2Ar$	$\rightarrow$	decay rate	$300^{o}K$	$1.1 \pm 0.4 \times 10^{-32} cm^{6}/s$	8
$Ar^{2+}(^{3}P) + Ar + Ar$	$\rightarrow$	$Ar^{+} + Ar^{+} + Ar$	$300^{o}K$	$1.3 \pm 0.2 \times 10^{-30} cm^{6}/s$	2
$Kr(^{3}P_{2}) + 2Ar$	$\rightarrow$	decay rate	$300^{o}K$	$1.0 \pm 0.4 \times 10^{-33} cm^{6}/s$	8
$Kr^{*}(^{3}P_{1}) + 2Kr$	$\rightarrow$	$Kr_{2}^{*}(0_{u}^{+}) + Kr$	$300^{o}K$	$2.2 \times 10^{-32} cm^{6}/s$	19
$Kr^{*}(^{3}P_{1}) + 2Kr$	$\rightarrow$	$Kr_{2}^{*}(^{1,3}\Sigma_{g}^{+}) + Kr$	$300^{o}K$	$4.4 \times 10^{-32} cm^{6}/s$	19
$Kr^{2+} + Kr + Kr$	$\rightarrow$	$Kr^{+} + Kr^{+} + Kr$	$300^{o}K$	$2.2 \pm 0.5 \times 10^{-30} cm^{6}/s$	2
$Xe^{*}(^{3}P_{1}) + 2Xe$	$\rightarrow$	$Xe_{2}^{*}(0_{u}^{+}) + Xe$	$300^{o}K$	$3.4 \times 10^{-32} cm^{6}/s$	19
$Xe(^{3}P_{2}) + 2Xe$	$\rightarrow$	$Xe_{2}^{*}(^{3}\Sigma_{u}^{+}) + Xe$	$300^{o}K$	$8.0 \pm 0.7 \times 10^{-32} cm^{6}/s$	20
$Xe^{2+} + Xe + Xe$	$\rightarrow$	$Xe^{+} + Xe^{+} + Xe$	$300^{o}K$	$2.7 \pm 0.5 \times 10^{-30} cm^{6}/s$	2
Atomic Noble-Diatomic Halogen (Homogeneous) Reactants					
$Ar(^{1}P_{1}) + F_{2}$	$\rightarrow$	quenching	$300^{o}K^{a}$	$1.3 \times 10^{-9} cm^{3}/s$	11
$Ar(^{3}P_{o}) + F_{2}$	$\rightarrow$	quenching	$300^{o}K$	$9.0 \times 10^{-10} cm^{3}/s$	10

Reaction	Temperature, Velocity or Energy	Cross Section or Reaction Rate	Reference
$Ar(^3P_1) + F_2 \rightarrow$ quenching	300^oK	$8.9x10^{-10}cm^3/s$	10
$Ar(^3P_2) + F_2 \rightarrow$ quenching	300^oK	$7.5x10^{-10}cm^3/s$	10
$Ar(^1P_1) + Cl_2 \rightarrow$ quenching	300^oK	$2.8x10^{-10}cm^3/s$	10
$Ar(^3P_o) + Cl_2 \rightarrow$ quenching	300^oK	$7.2x10^{-10}cm^3/s$	10
$Ar(^3P_1) + Cl_2 \rightarrow$ quenching	300^oK	$2.7x10^{-10}cm^3/s$	10
$Kr(^3P_2) + F_2 \rightarrow$ quenching	300^oK	$7.2x10^{-10}cm^3/s$	10
$Kr(^3P_2) + Cl_2 \rightarrow$ quenching	300^oK	$7.3x10^{-10}cm^3/s$	10
$Kr(^3P_2) + Br_2 \rightarrow$ quenching	300^oK	$6.1x10^{-10}cm^3/s$	10
$Xe(^3P_2) + F_2 \rightarrow$ quenching	300^oK	$7.5x10^{-10}cm^3/s$	10
$Xe(^3P_2) + Cl_2 \rightarrow$ quenching	300^oK	$7.2x10^{-10}cm^3/s$	10
$Xe(^3P_2) + Br_2 \rightarrow$ quenching	300^oK	$6.0x10^{-10}cm^3/s$	10
Atomic Noble-Diatomic Halogen (Non-Homogeneous) Reactants			
$Ar(^3P_2) + ClF \rightarrow$ quenching	300^oK	$7.4x10^{-10}cm^3/s$	10
$Ar(^3P_2) + ICl \rightarrow$ quenching	300^oK	$6.1x10^{-10}cm^3/s$	10

Reaction			Temperature, Velocity or Energy	Cross Section or Reaction Rate	Reference
$Kr(^3P_2) + ClF$	$\rightarrow$	quenching	300^oK	$6.8x10^{-10}cm^3/s$	10
$Kr(^3P_2) + ICl$	$\rightarrow$	quenching	300^oK	$4.9x10^{-10}cm^3/s$	10
$Kr(^3P_2) + IBr$	$\rightarrow$	quenching	300^oK	$7.1x10^{-10}cm^3/s$	10
$Xe(^3P_2) + ClF$	$\rightarrow$	quenching	300^oK	$6.0x10^{-10}cm^3/s$	10
$Xe(^3P_2) + ICl$	$\rightarrow$	quenching	300^oK	$5.0x10^{-10}cm^3/s$	10
Atomic Noble-NF_3 and Freon Reactants					
$Ar + NF_3$	$\rightarrow$	$NF_2 + F + Ar$	$1330 - 2000^oK$	$2.31x10^{15}exp(-20500/T)cm^3/s$	22
$Ar(^3P_o) + NF_3$	$\rightarrow$	quenching	300^oK	$7x10^{-11}cm^3/s$	10
$Ar(^3P_2) + NF_3$	$\rightarrow$	quenching	300^oK	$1.4x10^{-10}cm^3/s$	10
$Ar(^3P_o) + CF_4$	$\rightarrow$	quenching	300^oK	$4x10^{-11}cm^3/s$	10
$Ar(^3P_2) + CF_4$	$\rightarrow$	quenching	300^oK	$4x10^{-11}cm^3/s$	10
$Ar(^3P_o) + CF_3Cl$	$\rightarrow$	quenching	300^oK	$2.7x10^{-10}cm^3/s$	10
$Ar(^3P_2) + CF_3Cl$	$\rightarrow$	quenching	300^oK	$2.2x10^{-10}cm^3/s$	10

Reaction	Temperature, Velocity or Energy	Cross Section or Reaction Rate	Reference
$Ar(^3P_o) + CF_2Cl_2 \rightarrow$ quenching	300^oK	$5.7x10^{-10}cm^3/s$	10
$Ar(^3P_2) + CF_2Cl_2 \rightarrow$ quenching	300^oK	$3.7x10^{-10}cm^3/s$	10
$Ar(^3P_o) + CCl_3F \rightarrow$ quenching	300^oK	$4.3x10^{-10}cm^3/s$	10
$Ar(^3P_2) + CCl_3F \rightarrow$ quenching	300^oK	$5.5x10^{-10}cm^3/s$	10
$Ar(^3P_o) + CF_3Br \rightarrow$ quenching	300^oK	$3.4x10^{-10}cm^3/s$	10
$Ar(^3P_2) + CF_3Br \rightarrow$ quenching	300^oK	$3.1x10^{-10}cm^3/s$	10
$Ar(^3P_2) + CF_3I \rightarrow$ quenching	300^oK	$4.7x10^{-10}cm^3/s$	10
$Kr(^3P_2) + NF_3 \rightarrow$ quenching	300^oK	$1.2x10^{-10}cm^3/s$	10
$Kr(^3P_2) + CF_4 \rightarrow$ quenching	300^oK	$7x10^{-13}cm^3/s$	10
$Kr(^3P_2) + CF_3Cl \rightarrow$ quenching	300^oK	$1.4x10^{-10}cm^3/s$	10
$Kr(^3P_2) + CF_3Br \rightarrow$ quenching	300^oK	$5.0x10^{-10}cm^3/s$	10
$Kr(^3P_2) + CF_3I \rightarrow$ quenching	300^oK	$4.9x10^{-10}cm^3/s$	10
$Kr(^3P_2) + CCl_4 \rightarrow$ quenching	300^oK	$6.9x10^{-10}cm^3/s$	10
$Xe(^3P_2) + NF_3 \rightarrow$ quenching	300^oK	$9x10^{-11}cm^3/s$	10
$Xe(^3P_2) + CF_4 \rightarrow$ quenching	300^oK	$3x10^{-13}cm^3/s$	10

Reaction	Temperature, Velocity or Energy	Cross Section or Reaction Rate	Reference
$Xe^*(25f) + CCl_3F \rightarrow Xe^+$	300^oK	$3.8 \pm 0.7 \times 10^{-7} cm^3/s$	23
$Xe^*(27f) + CCl_3F \rightarrow Xe^+$	300^oK	$4.6 \pm 0.9 \times 10^{-7} cm^3/s$	23
$Xe^*(28f) + CCl_3F \rightarrow Xe^+$	300^oK	$4.4 \pm 0.9 \times 10^{-7} cm^3/s$	23
$Xe^*(29f) + CCl_3F \rightarrow Xe^+$	300^oK	$4.7 \pm 0.9 \times 10^{-7} cm^3/s$	23
$Xe^*(31f) + CCl_3F \rightarrow Xe^+$	300^oK	$5.9 \pm 1.1 \times 10^{-7} cm^3/s$	23
$Xe^*(33f) + CCl_3F \rightarrow Xe^+$	300^oK	$6.1 \pm 1.2 \times 10^{-7} cm^3/s$	23
$Xe^*(37 \pm 1)f + CCl_3F \rightarrow Xe^+$	300^oK	$5.8 \pm 1.2 \times 10^{-7} cm^3/s$	23
$Xe^*(38 \pm 1)f + CCl_3F \rightarrow Xe^+$	300^oK	$6.3 \pm 1.1 \times 10^{-7} cm^3/s$	23
$Xe^*(40 \pm 2)f + CCl_3F \rightarrow Xe^+$	300^oK	$6.5 \pm 1.3 \times 10^{-7} cm^3/s$	23
$Xe(^3P_2) + CF_3Br \rightarrow$ quenching	300^oK	$4.2 \times 10^{-10} cm^3/s$	10
$Xe(^3P_2) + CF_3I \rightarrow$ quenching	300^oK	$5.2 \times 10^{-10} cm^3/s$	10
$Xe^*(25f) + CCl_4 \rightarrow Xe^+$	300^oK	$2.6 \pm 0.5 \times 10^{-7} cm^3/s$	23
$Xe^*(26f) + CCl_4 \rightarrow Xe^+$	300^oK	$2.2 \pm 0.4 \times 10^{-7} cm^3/s$	23
$Xe^*(27f) + CCl_4 \rightarrow Xe^+$	300^oK	$2.3 \pm 0.4 \times 10^{-7} cm^3/s$	23
$Xe^*(28f) + CCl_4 \rightarrow Xe^+$	300^oK	$2.5 \pm 0.5 \times 10^{-7} cm^3/s$	23

Reaction			Temperature, Velocity or Energy	Cross Section or Reaction Rate	Reference
$Xe^*(29f) + CCl_4$	$\rightarrow$	Xe^+	300^oK	$2.9 \pm 0.6 \times 10^{-7} cm^3/s$	23
$Xe^*(31f) + CCl_4$	$\rightarrow$	Xe^+	300^oK	$3.1 \pm 0.6 \times 10^{-7} cm^3/s$	23
$Xe^*(33f) + CCl_4$	$\rightarrow$	Xe^+	300^oK	$3.6 \pm 0.7 \times 10^{-7} cm^3/s$	23
$Xe^*(34f) + CCl_4$	$\rightarrow$	Xe^+	300^oK	$3.5 \pm 0.6 \times 10^{-7} cm^3/s$	23
$Xe^*(37 \pm 1)f + CCl_4$	$\rightarrow$	Xe^+	300^oK	$4.0 \pm 0.8 \times 10^{-7} cm^3/s$	23
$Xe^*(38 \pm 1)f + CCl_4$	$\rightarrow$	Xe^+	300^oK	$3.7 \pm 0.7 \times 10^{-7} cm^3/s$	23
$Xe^*(40 \pm 2)f + CCl_4$	$\rightarrow$	Xe^+	300^oK	$4.5 \pm 0.9 \times 10^{-7} cm^3/s$	23
$Xe^*(41 \pm 2)f + CCl_4$	$\rightarrow$	Xe^+	300^oK	$4.2 \pm 0.8 \times 10^{-7} cm^3/s$	23
Diatomic Noble-Halogen Reactants					
$Ar_2^+ + F^-$	$\rightarrow$	$ArF^* + Ar$	300^oK	$1.1 \times 10^{-6} cm^3/s$	21
$Ar_2^*(1_u) + F_2$	$\rightarrow$	quenching	300^oK	$5.2 \times 10^{-10} cm^3/s$	11
$Ar^+ + F^- + Ar$	$\rightarrow$	$ArF^* + Ar$	300^oK	$1.1 \times 10^{-6} cm^3/s$	21

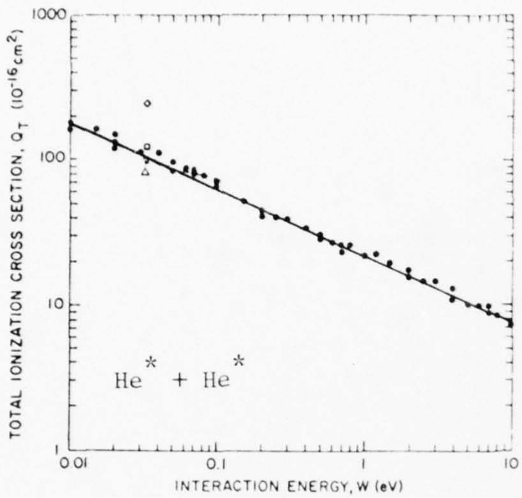
Reaction			Temperature, Velocity or Energy	Cross Section or Reaction Rate	Reference
			Halogen-Noble Reactants		
$Cl^- + He$	→	$Cl + He + e^-$	6 - 11eV	Graph 11	24
$Cl^- + Ne$	→	$Cl + Ne + e^-$	7 - 13eV	Graph 12	24
$Cl^- + Ar$	→	$Cl + Ar + e^-$	7 - 20eV	Graph 13	24
$Br^- + He$	→	$Br + He + e^-$	5 - 11eV	Graph 14	24
$Br^- + Ne$	→	$Br + Ne + e^-$	8 - 15eV	Graph 15	24
$Br^- + Ar$	→	$Br + Ar + e^-$	7 - 10eV	Graph 15	24
$Br^- + Kr$	→	$Br + Kr + e^-$	7 - 11eV	Graph 13	24
			Noble-Halogen-Noble and Halogen Reactants		
XeF(B) + He	→	quenching	300^oK^a	$2.0\pm0.26\times10^{-12}cm^3/s$	25
XeF(B) + Ne	→	quenching	300^oK^a	$<3\times10^{-13}cm^3/s$	25
XeF(B) + Ar	→	quenching	300^oK^a	$3\times10^{-12}cm^3/s$	25
XeF(B) + Xe	→	deactivation	300^oK^a	$3.6\times10^{-11}cm^3/s$	26
XeF(B) + XeF_2	→	quenching	300^oK	$2.6\pm0.3\times10^{-10}cm^3/s$	25
$ArF^* + F_2$	→	quenching	300^oK	$1.9\times10^{-19}\pm25\%cm^3/s$	27

Reaction	Temperature, Velocity or Energy	Cross Section or Reaction Rate	Reference
$Ar_2F^* + F_2 \rightarrow$ quenching	300^oK	$2.1x10^{-10} \pm 25\% cm^3/s$	27
$XeF^*(B) + F_2 \rightarrow$ deactivation	300^oK^a	$3.6x10^{-10} cm^3/s$	26
$XeF^*(B) + NF_3 \rightarrow$ deavtivation	300^oK^a	$2.4x10^{-11} cm^3/s$	26
Noble Halogen-Noble-Noble Reactants			
$ArF^* + 2Ar \rightarrow$ quenching	300^oK	$5.3x10^{-31} \pm 25\% cm^6/s$	27
$XeF^*(B) + 2Xe \rightarrow$ deactivation	300^oK^a	$2.36 \pm 0.53x10^{-29} cm^6/s$	26
Atomic Halogen-Diatomic Halogen (Homogeneous) Reactants			
$Cl + Br_2 \rightarrow BrCl + Br$	6.8 Kcal/mole	$11\ \mathring{A}^2$	28
$Cl + Br_2 \rightarrow BrCl + Br$	14.7 Kcal/mole	$14\ \mathring{A}^2$	28
$Br^*(4^2P_{1/2}) + Br_2 \rightarrow Br + Br_2$	295^oK	$8.0 \pm 0.8x10^{-13} cm^3/s$	29
$I(5^2P_{1/2}) + Cl_2 \rightarrow$ deactivation	300^oK^a	$1.7 \pm 0.2x10^{-12} cm^3/s$	30
$I(5^2P_{1/2}) + Br_2 \rightarrow$ deactivation	300^oK^a	$5.2 \pm 0.3x10^{-11} cm^3/s$	30
$I^*(5^2P_{1/2}) + I_2 \rightarrow$ deactivation	300^oK^a	$3.1 \pm 0.5x10^{-11} cm^3/s$	30

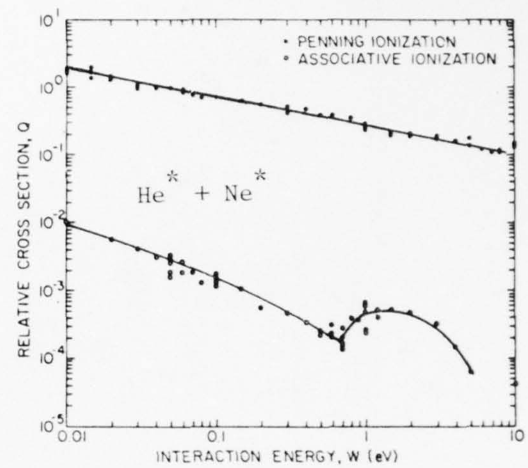
Reaction			Temperature, Velocity or Energy	Cross Section or Reaction Rate	Reference
Atomic Halogen-Other Halogen Reactants					
$Br + IBr$		$Br_2 + I$	295^oK	$3.5x10^{-11}cm^3/s$	29
$I(5^2P_{1/2}) + BrCl$	$\rightarrow$	deactivation	300^oK[a]	$2.7\pm0.2x10^{-11}cm^3/s$	30
$I(5^2P_{1/2}) + ICl$	$\rightarrow$	deactivation	300^oK[a]	$2.3\pm0.2x10^{-11}cm^3/s$	30
$I(5^2P_{1/2}) + IBr$	$\rightarrow$	deactivation	300^oK[a]	$6.6\pm0.3x10^{-11}cm^3/s$	30
$Cl^- + CClF_2^+$	$\rightarrow$	neutralization	300^oK	$4.1\pm0.4x10^{-8}cm^3/s$	31
$Cl^- + CCl_3^+$	$\rightarrow$	neutralization	300^oK	$4.5\pm0.5x10^{-8}cm^3/s$	31

FOOTNOTE

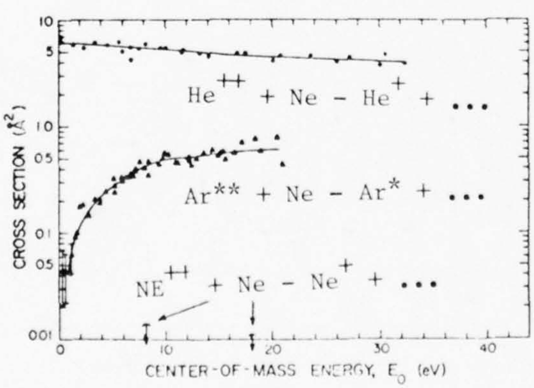
a. These temperatures are in doubt since they were not found in the reference.



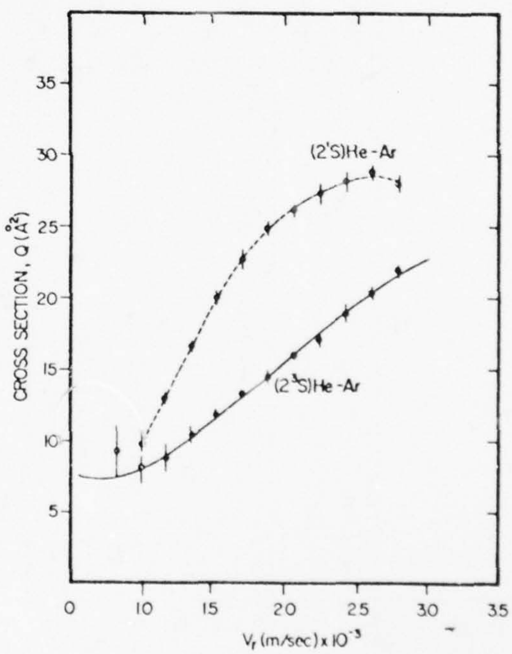
Graph 1



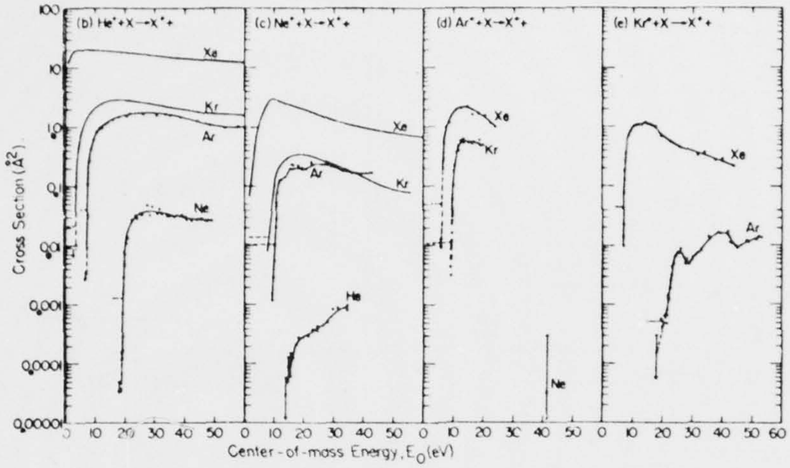
Graph 2



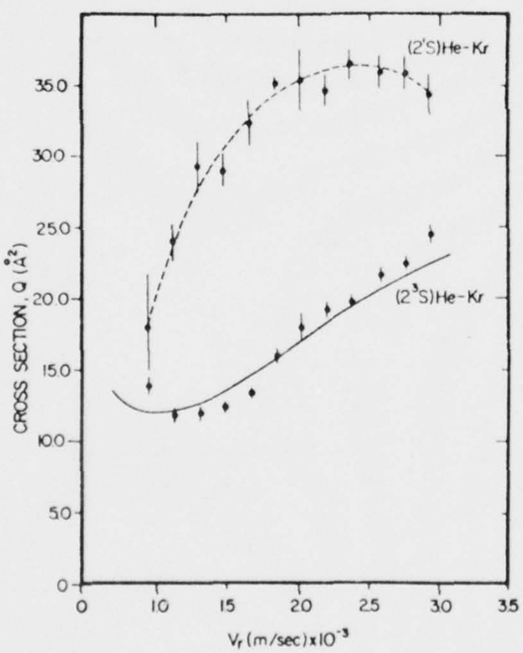
Graph 3



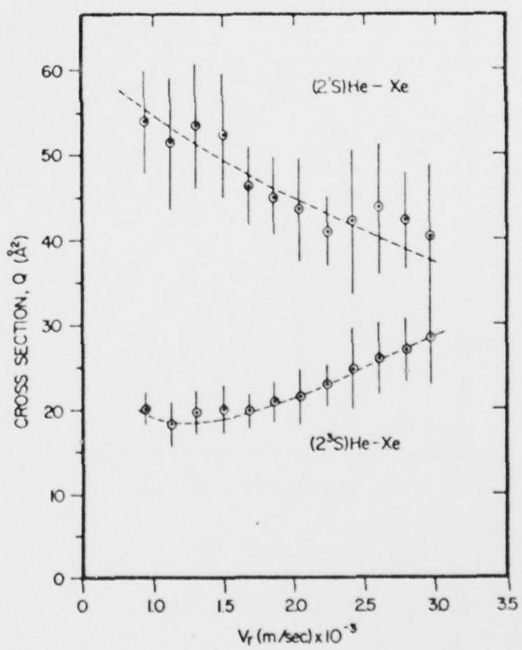
Graph 4



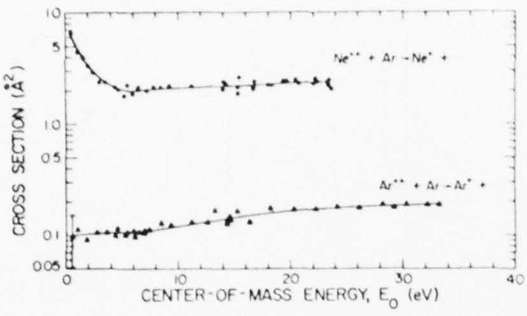
Graph 5



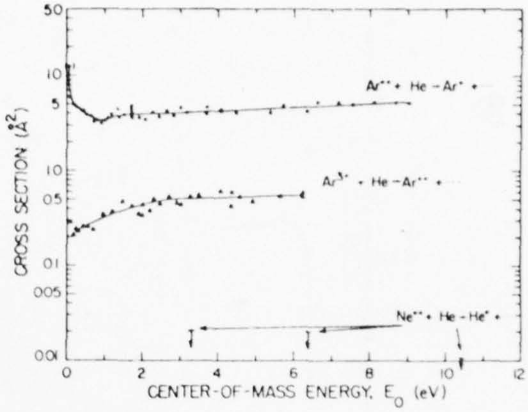
Graph 6



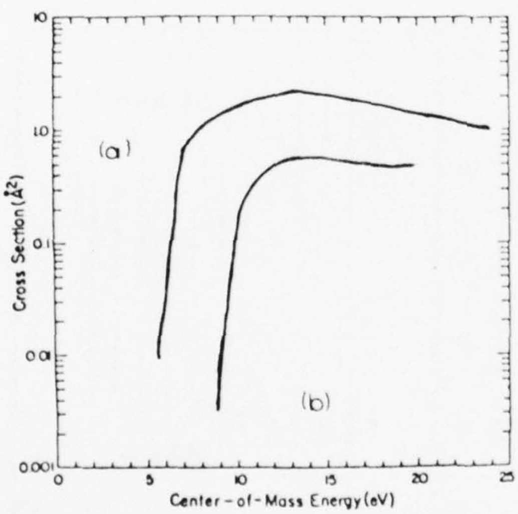
Graph 7



Graph 8



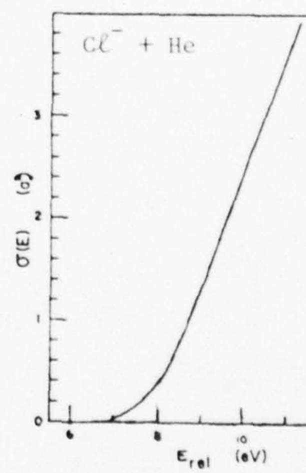
Graph 9



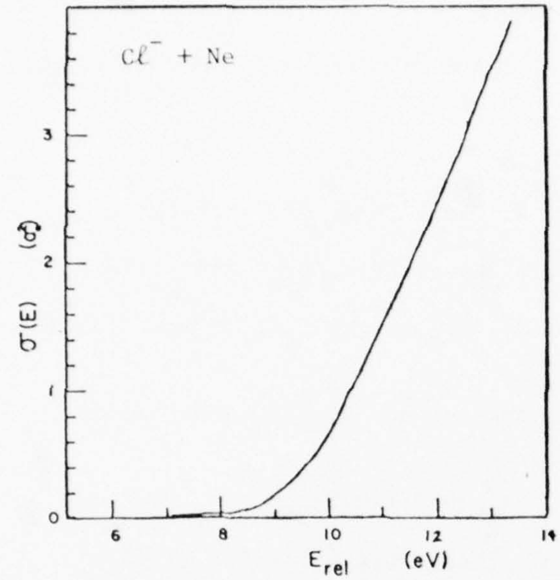
Graph 10

(a) $Ar^+ + Xe \rightarrow Xe^+ + Ar$

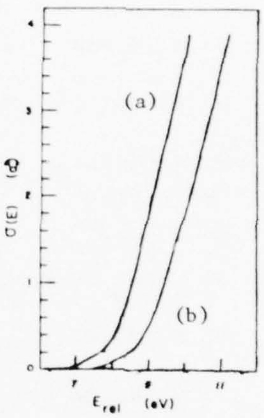
(b) $Ar^+ + Kr \rightarrow Kr^+ + Ar$



Graph 11



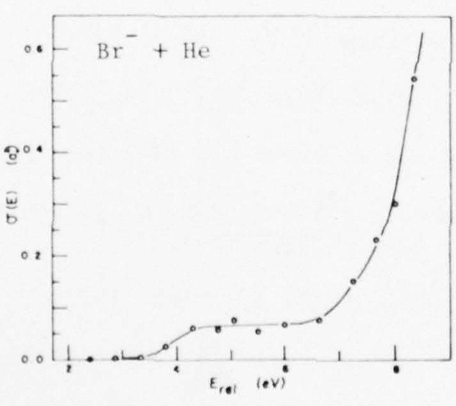
Graph 12



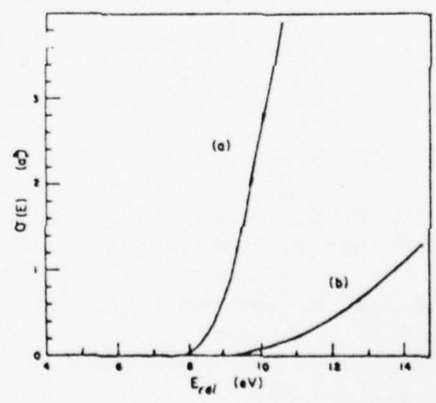
Graph 13

(a) $Cl^- + Ar \rightarrow Cl + Ar + e^-$

(b) $Br^- + Kr \rightarrow Br + Kr + e^-$



Graph 14



Graph 15

(a) $Br^- + Ar \rightarrow Br + Ar + e^-$

(b) $Br^- + Ne \rightarrow Br + Ne + e^-$

References

1. R. H. Neynaber, G. D. Magnuson, and S. Y. Tang, J. Chem. Phys. 68, 5112 (1978).

2. R. Johnsen and M. A. Biondi, Phys. Rev. A 18, 996 (1978).

3. R. H. Neynaber and S. Y. Tang, J. Chem. Phys. 67, 5619 (1977).

4. W. B. Maier II and B. Stewart, J. Chem. Phys. 68, 4228 (1978).

5. D. W. Martin, R. W. Gregor, R. M. Jordan, and P. E. Siska, J. Chem. Phys. 69, 2833 (1978).

6. M. R. Woodard, R. C. Sharp, M. Seeley, and E. E. Muschlitz, Jr., J. Chem. Phys. 69, 2978 (1978).

7. W. B. Maier II, J. Chem. Phys. 69, 3077 (1978).

8. J. H. Kolts and D. W. Setser, J. Chem. Phys. 68, 4848 (1978).

9. R. S. F. Chang and D. W. Setser, J. Chem. Phys. 69, 3885 (1978).

10. J. E. Velazco, J. H. Kolts, and D. W. Setser, J. Chem. Phys. 69, 4357 (1978).

11. C. H. Chen, J. B. Judish, and M. G. Payne, J. Phys. B. 11, 2189 (1978).

12. V. Lefevre-Seguin and M. Leduc, J. Phys. B 10, 2157 (1977).

13. G. Myers and A. J. Cunningham, J. Chem. Phys. 67, 3352 (1977).

14. G. Myers and A. J. Cunningham, J. Chem. Phys. 67, 1942 (1977).

15. F. C. Fehsenfeld, A. L. Schmeltekopf, P. D. Goldan, H. I. Schiff, and E. E. Ferguson, J. Chem. Phys. 44, 4087 (1966).

16. F. W. Lee and C. B. Collins, J. Chem. Phys. 67, 2798 (1977).

17. L. C. Pitchford and R. Deloche, J. Chem. Phys. 68, 1185 (1978).

18. R. Johnsen, J. MacDonald, and M. A. Biondi, J. Chem. Phys. 68, 2991 (1978).

19. R. Brodmann and G. Zimmerer, J. Phys. B 10, 3395 (1977).

20. P. Millet, A. Birot, H. Brunet, J. Galy, B. Pons-Germain, and J. L. Teyssier, J. Chem. Phys. 69, 92 (1978).

21. M. Rokni, J. H. Jacob, and J. A. Mangano, Phys. Rev. A 16, 2216 (1977).

22. W. D. Breshears and P. F. Bird, J. Chem. Phys. 68, 2996 (1978).

23. G. W. Foltz, C. J. Latimer, G. F. Hildebrandt, F. G. Kellert, K. A. Smith, W. P. West, F. B. Dunning, and R. F. Stebbings, J. Chem. Phys. 67, 1352 (1977).

24. B. T. Smith, W. R. Edwards III, L. D. Doverspike, and R. L. Champion, Phys. Rev. A 18, 945 (1978).

25. C. H. Fisher and R. E. Center, J. Chem. Phys. 69, 2011 (1978).

26. J. G. Eden and R. W. Waynant, J. Chem. Phys. 68, 2850 (1978).

27. C. H. Chen, M. G. Payne, and J. P. Judish, J. Chem. Phys. 69, 1626 (1978).

28. J. J. Valentini and Y. T. Lee, J. Chem. Phys. 67, 4866 (1977).

29. J. R. Wiesenfeld and G. L. Wolk, J. Chem. Phys. 69, 1805 (1978).

30. H. Hofmann and S. R. Leone, J. Chem. Phys. 69, 641 (1978).

31. D. Smith, M. J. Church, and T. M. Miller, J. Chem. Phys. 68, 1224 (1978).

B-2. HIGH ENERGY HEAVY PARTICLE — HEAVY PARTICLE COLLISIONS

CONTENTS

Introduction

This section is concerned with charge changing, ionizing, and excitation collisions when fast (Energy > 1 keV) heavy projectiles traverse a gas. The data are in the form of cross sections; the behaviour in "thick" (high density) gas targets is considered elsewhere (Chapter G). The projectiles included here are positive ions and atoms of hydrogen and helium as well as of elements whose nuclear charge lies between 32 and 65 (fission fragments); these are considered to be the projectiles of interest in nuclear pumped laser mechanisms. For many mechanisms the data coverage for the more massive projectiles ($32 \leq Z \leq 65$) is very limited and sometimes representative data for other projectiles have been included to illustrate the general trends expected. Most of the data presented here are for targets of the rare gases (He, Ne, Ar, Kr, and Xe) and stable diatomic gases (H_2, N_2, O_2, and CO). Other target species of interest are the halogens, H, N, C, O, CO_2, H_2O, HF, Hg, Cd, U, and UF_6; data on these cases have been included where possible, but at best they are fragmentary and at worst nonexistent.

To produce a manageable data set it has been found to be necessary to limit, or omit altogether, coverage of certain mechanisms of peripheral interest; we instead refer the reader to standard works on the revelant subjects. Processes involving fast negative ions have been omitted entirely, although there are substantial data on these, particularly for the hydrogenic species. For projectiles traversing a thick target there will be few negative ions in the beams since the extra electron is weakly bound and readily removed by collision; moreover, it seems unlikely that negative ions will be produced in any reactor pumped laser configuration. For coverage of the cross sections for destruction and formation of negative hydrogen ions the reader is referred to the review by Tawara and Russek [Rev. Mod. Phys. 45, 178 (1973)]. We have also omitted coverage of fast molecular ions traversing gases since there is no reason to expect molecular species from nuclear reactions. For a bibliography on fast molecular dissociation, the reader should consult the book by McClure and Peek (Dissociation in Heavy Particle Collisions, Wiley Interscience, New York, 1972). Excitation of gases by heavy projectiles is a subject where there is a vast amount of relevant data, far too extensive to be reproduced here in its entirety. Coverage has been restricted to only a limited group of excited states for any one of the reactions of interest. A broader coverage with a complete compendium of data can be found in the book by Thomas (Excitation in Heavy Particle Collisions, Wiley Interscience, New York, 1972). It should of course always be remembered that excitation of a dense gas is primarily due to secondary electrons liberated by ionization of the medium; direct excitation by the fast heavy projectile is likely to be a small component.

For many of the mechanisms involving light projectiles (hydrogen and helium) there is an abundance of data and analyses have provided semi-empirical algebraic representations of how cross section varies with energy. Where available, these formulae have been reproduced since they are more convenient than data points for use in any modelling program.

General References:

1. C. F. Barnett, J. A. Ray, E. Ricci, I. Wilker, E. W. McDaniel, E. W. Thomas, and H. B. Gilbody, "Atomic Data for Controlled Fusion Research," Report ORNL 5206, Controlled Fusion Atomic Data Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee (February 1977).

2. H. D. Betz, Rev. Mod. Phys. 44, 465 (1972).

3. R. C. Dehmel, H. K. Chau, and H. H. Fleishmann, Atomic Data 5, 231 (1973).

4. H. H. Lo and W. L. Fite, Atomic Data 1, 305 (1973).

5. G. W. McClure and J. M. Peek, Dissociation in Heavy Particle Collisions, Wiley, New York (1972).

6. H. Tawara and A. Russek, Rev. Mod. Phys. 45, 178 (1973).

7. E. W. Thomas, Excitation in Heavy Particle Collisions, Wiley, New York (1972).

Tabular Data B-2.1. Ionization of He, Ne, Ar, Kr, H_2, N_2, and O_2 by Protons.

$$H^+ + X \rightarrow H^+ + X^+ + e^a$$

We suggest use of the following semi-empirical analytic expression by Green and McNeal which adequately represents the available data; applicable parameters are shown in tabular form below.

$$\text{General analytic form} \quad \sigma(E) = \frac{\sigma_o (Za)^\Omega (E-I)^\nu}{J^{\Omega+\nu} + E^{\Omega+\nu}} \qquad (1)$$

$$\text{High energy asymptotic form} \quad \sigma(E) = \sigma_o \left(\frac{Za}{E}\right)^\Omega$$

$\sigma(E)$ = Cross section in cm^2 at impact energy E(keV)

σ_o = 10^{-16} cm^2

Z = Number of electrons in one molecule of gas

I = Ionization threshold of gas (keV)

Ω = 0.75[b]

ν = See table below[c]

a,J = Parameters obtained by fitting to data. See below.

Target Characteristics			Three Parameters (ν, J and a) Varied [e]			Two Parameters (J and a) Varied (ν fixed = 1.00)[e]		
Target Species	Z	I^d (keV)	ν	J (keV)	a (keV)	ν	J (keV)	a (keV)
He	2	0.0247	1.25	58.86	65.05	1.00	69.05	71.15
Ne	10	0.0215	1.08	70.17	41.56	1.00	74.59	43.14
Ar	18	0.0157	1.00	46.18	102.78	1.00	47.67	94.33
Kr	36	0.0139	1.00	44.60	77.78	1.00	45.80	70.72
H_2	2	0.0156	1.02	47.62	171.50	1.00	48.62	174.0
N_2	14	0.0155	0.77	67.15	120.36	1.00	55.31	106.0
O_2	16	0.0125	0.82	69.08	105.62	1.00	59.91	97.0
Others			(see note f below)					

Reference A. E. S. Green and R. J. McNeal, J. Geophys. Res. 76, 133 (1971).

C. F. Barnett, et al., "Atomic Data for Controlled Fusion Research" Oak Ridge National Laboratory Report ORNL 5206.

Notes (a) Strictly speaking the cross section is the sum $\sum_m m\ \sigma_m$ of cross sections for the process $H^+ + X \rightarrow H^+ + X^m$ + me where m varies from 1 to the nuclear charge of X. In practise m = 1 will predominate.

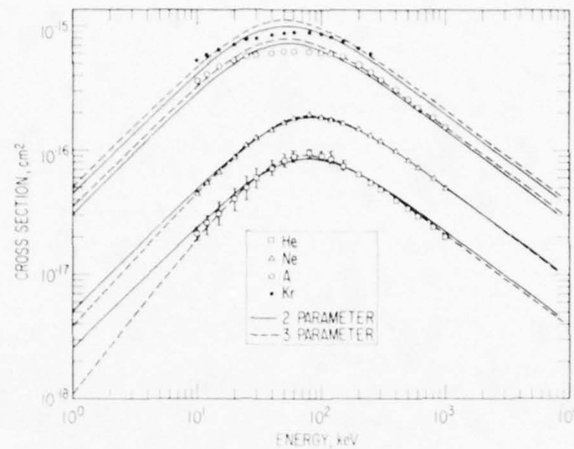
(b) This value of Ω is consistent with the asymptotic high energy behaviour of the Born Approximation.

(c) This parameter is taken as unity for the two parameter fit and is varied in the three parameter fit.

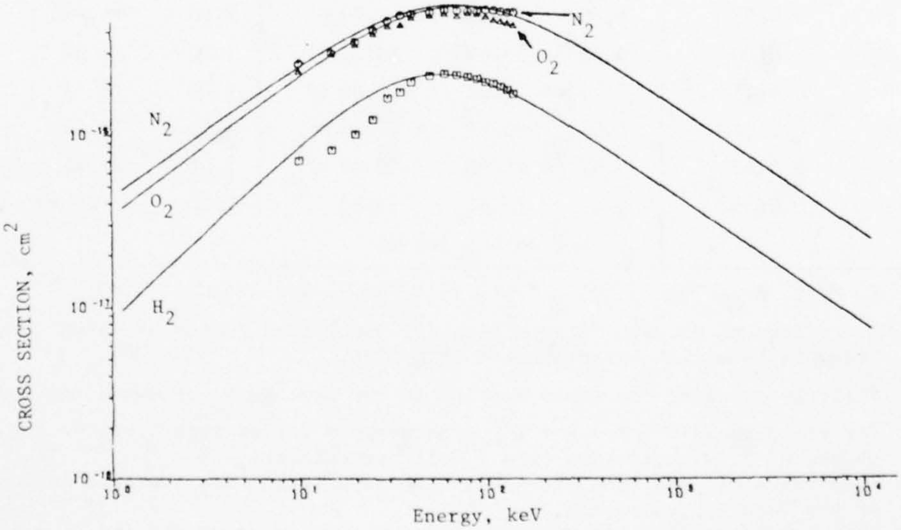
(d) Handbook of Chemistry and Physics, 46th Edition (Chemical Rubber Pub. Co., Cleveland, 1966).

(e) The three parameter form is most accurate but differs significantly from the two parameter form only for He.

(f) For other gases a reasonable estimate may be made by using average values of ν, J and a with appropriate values of Z and I.



(a) Cross sections of proton impact ionization for rare gases. The solid curves are plots of equation 1 with $\Omega = 0.75$, $\nu = 1.00$, and two parameters (a and J) adjusted to the values shown in the Table. The dashed curves are similar plots with $\Omega = 0.75$, and ν, a, and J adjusted. The error bars on the He curve show the spread in reported data at energies where more than one set of data is available. The curves were taken from Green and McNeal.



(b) Cross sections of proton impact ionization of molecular gases. Curves were taken from Green and McNeal. Data points are from the work of De Heer et al., Physica 32, 1766 (1966).

Graphical Data B-2.2. Cross sections of proton impact ionization for (a) rare gases and (b) molecular gases.

Tabular Data B-2.3. Ionization of He, Ne, Ar, Kr, Xe, H_2, N_2, and O_2 by H atoms.

$$H + X \rightarrow H + X^+ + e^{\ a}$$

We suggest use of the following semi-empirical analytic expression by Green and McNeal which adequately represents the available data; applicable parameters are shown in tabular form below.

General analytic form $$\sigma(E) = \frac{\sigma_o (Za)^{\Omega} \ (E-I)^{\nu}}{J^{\Omega+\nu} + E^{\Omega+\nu}} \qquad (1)$$

High energy asymptotic form $$\sigma(E) = \sigma_o \left(\frac{Za}{E}\right)$$

$\sigma(E)$ = Cross section in cm^2 at impact energy E(keV)

σ_o = 10^{-16} cm^2

Z = Number of electrons in one molecule of gas

I = Ionization threshold of gas (keV)

Ω = 0.75[b]

ν = See table below[c]

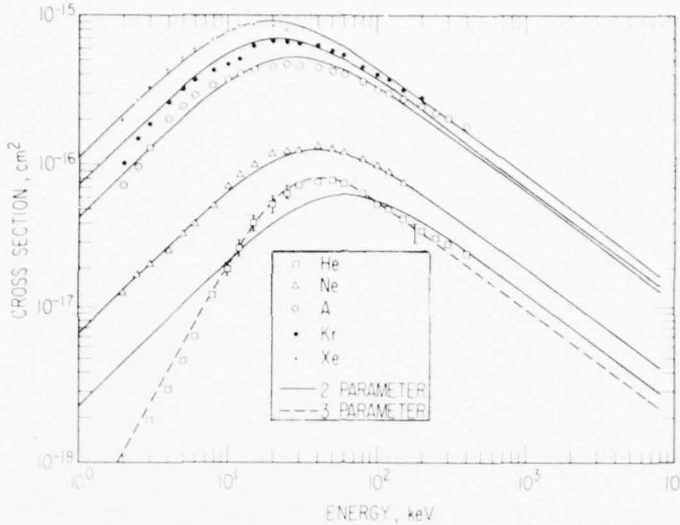
a,J = Parameters obtained by fitting to data. See below.

Target Characteristics			Three Parameters (ν, J and a) Varied[e]			Two Parameters (J and a) Varied (ν fixed = 1.00)[e]		
Target Species	Z	I[d] (keV)	ν	J (keV)	a (keV)	ν	J (keV)	a (keV)
He	2	0.0247	1.83	28.85	25.35	1.00	53.11	35.75
Ne	10	0.0215	0.97	36.10	12.22	1.00	34.78	11.86
Ar	18	0.0157	0.70	36.88	41.72	1.00	24.49	31.34
Kr	36	0.0139	0.98	19.69	18.31	1.00	19.38	18.07
Xe	54	0.0121	1.15	13.22	11.46	1.00	16.61	14.67
H_2	2	0.0156	1.04	23.68	47.45	1.00	24.67	48.70
N_2	14	0.0155	0.63	28.80	38.82	1.00	16.91	27.10
O_2	16	0.0125	0.43	73.11	73.88	1.00	No fit	
Others			(see note f below)					

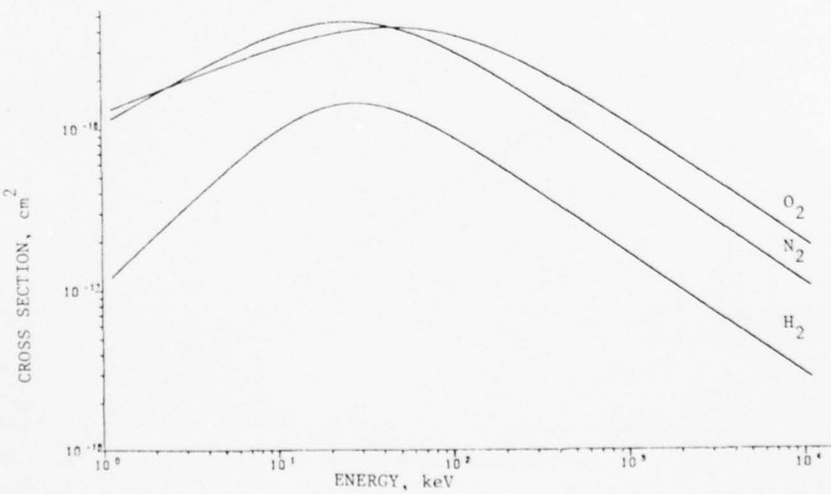
Reference A. E. S. Green and R. J. McNeal, J. Geophys. Res. 76, 133 (1971).

C. F. Barnett et al., "Atomic Data for Controlled Fusion Research" Oak Ridge National Laboratory Report ORNL 5206.

Notes
(a) Strictly speaking the cross section is the sum $\sum_m m\,\sigma_m$ of cross sections for the process $H + X \rightarrow H + X^{m+} + me$ where m varies from 1 to the nuclear charge of X. In practise m = 1 will predominate.
(b) This value of Ω is consistent with the asymptotic high energy behaviour of the Born Approximation.
(c) This parameter is taken as unity for the two parameter fit and is varied in the three parameter fit.
(d) Handbook of Chemistry and Physics, 46th Edition (Chemical Rubber Pub. Co. Cleveland, 1966).
(e) The three parameter form is most accurate but differs significantly from the two parameter form only for He; the two parameter fit does not work for O_2.
(f) For other gases a reasonable estimate may be made by using average values of ν, J and a with appropriate values of Z and I.

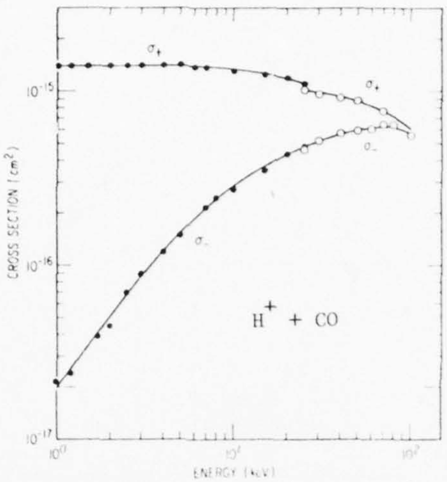


(a) Cross sections of hydrogen atom impact ionization for rare gases. The dashed curves were obtained by varying ν, a, and J with Ω = 0.75. The solid curves were obtained with Ω = 0.75, ν = 1.00, and a and J varied. The error bars on the He curve show the spread in reported data at energies where more than one set of data is available. The data were taken from Green and McNeal.

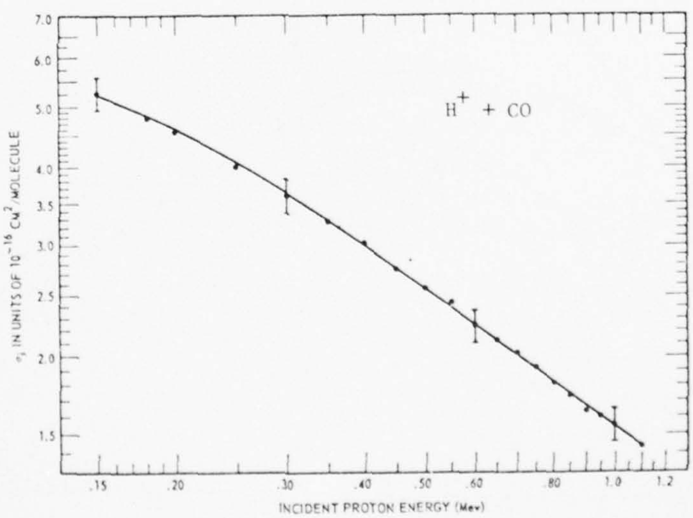


(b) Cross sections for H atom impact *ionization* of molecular gases. Because there are large discrepancies between experimental measurements we have shown no data points. The lines were plotted from the three parameter fit of Green and McNeal.

Graphical Data B-2.4. Cross sections for H atom impact ionization of (a) rare gases and (b) molecular gases.

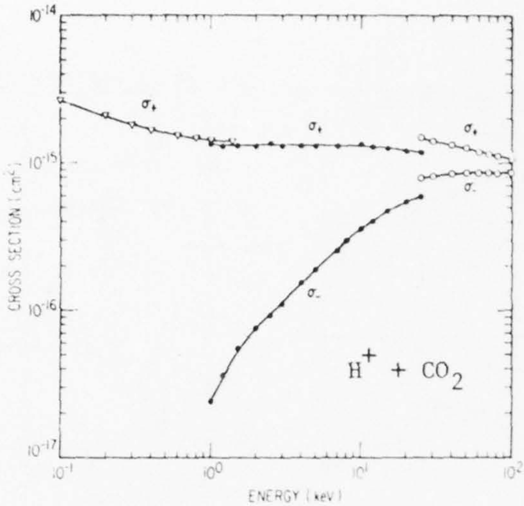


(a) Cross sections for production of slow positive and slow negative ions by H^+ impact on CO. σ_+ exceeds σ_- at low energies because σ_+ includes a component due to formation of slow positive ions as a result of charge pickup by the proton. R. J. McNeal, J. Chem. Phys. 53, 4308 (1970); and J. Desesquelles et al., Compt. Rend. B 262, 1329 (1966).

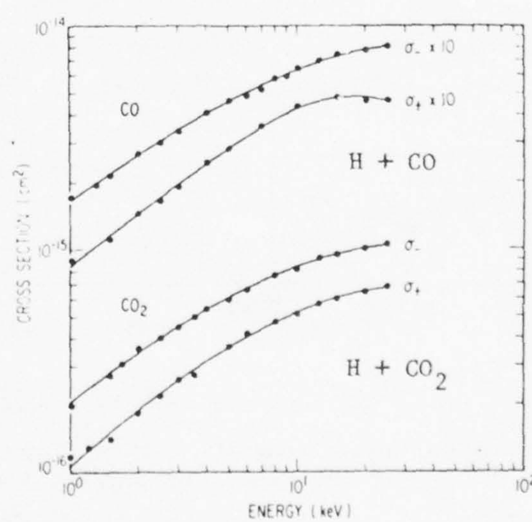


(b) Cross sections for ionization of CO by protons. J. W. Hooper, D. S. Harmer, D. W. Martin, and E. W. McDaniel, Phys. Rev. 125., 2000 (1962).

Graphical Data B-2.5. Ionization of CO by H^+.



Graphical Data B-2.6. Cross sections for production of slow positive and slow negative ions by H^+ impact on CO_2. σ_+ exceeds σ_- at low energies because σ_+ includes a significant component due to formation of slow positive ions as a result of charge pick up by the proton. R. J. McNeal, J. Chem. Phys. 53, 4308 (1970); J. Desesquelles et al., Compt. Rend. B 262, 1339 (1966); and D. W. Koopman, Phys. Rev. 166, 57 (1968).

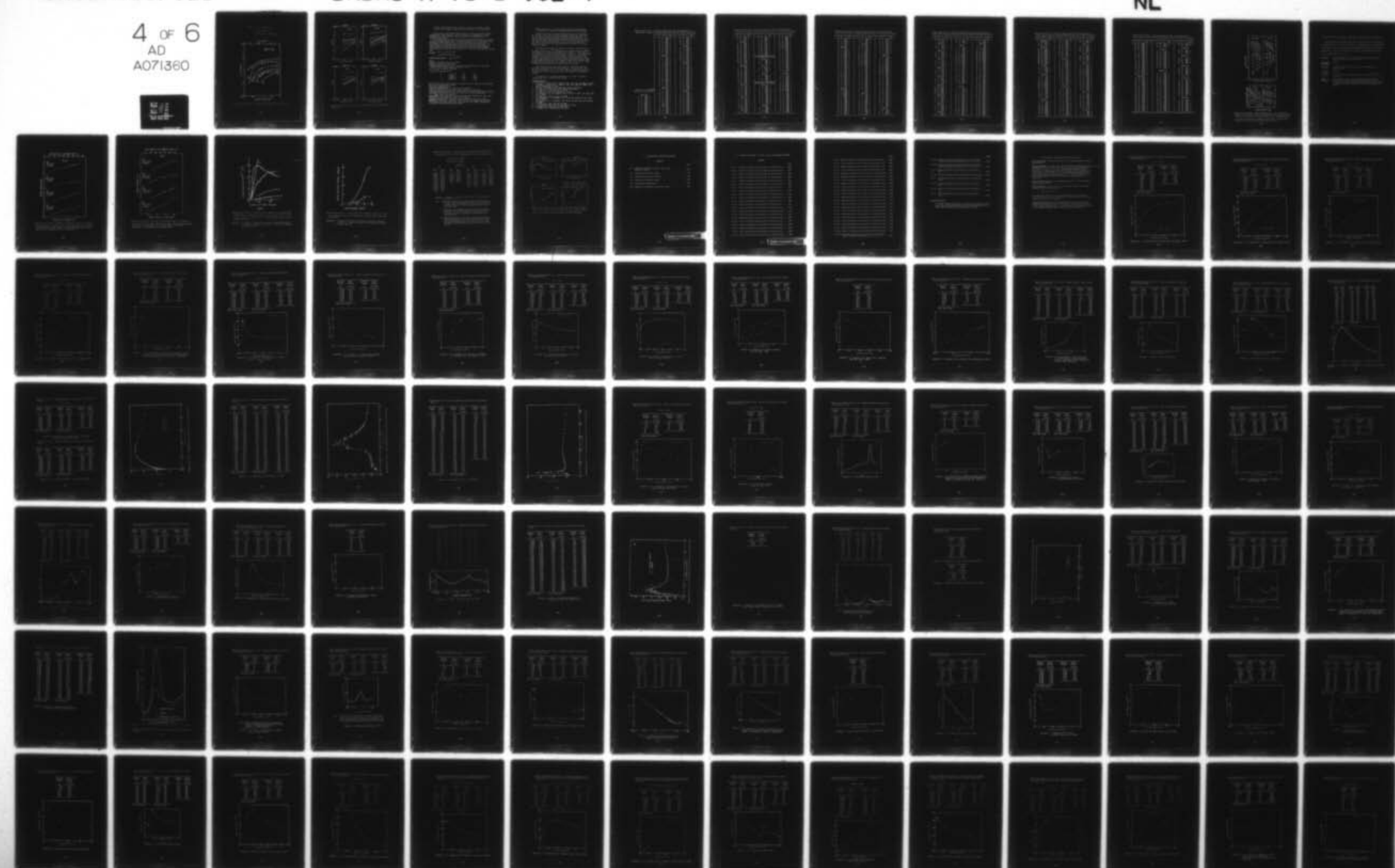


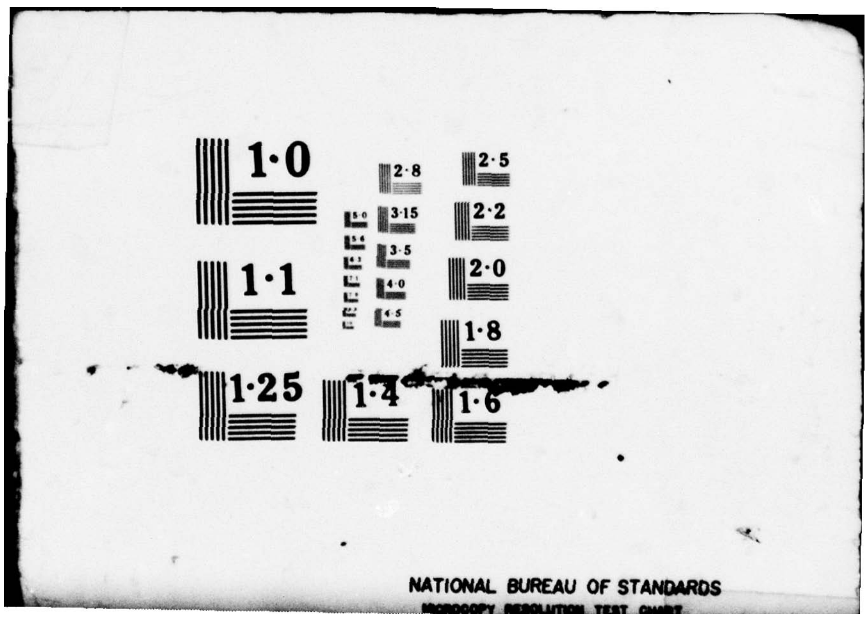
Graphical Data B-2.7. Cross sections for production of slow positive and slow negative ions by impact of H on CO and CO_2. The values for σ_- exceed those for σ_+ because σ_- includes a component due to electrons stripped from the incoming H projectile. R. J. McNeal, J. Chem. Phys. 53, 4308 (1970).

AD-A071 360 ARMY MISSILE RESEARCH AND DEVELOPMENT COMMAND REDSTO--ETC F/G 20/5
COMPILATION OF DATA RELEVANT TO NUCLEAR PUMPED LASERS. VOLUME I--ETC(U)
DEC 78 E W MCDANIEL, M R FLANNERY, E W THOMAS

UNCLASSIFIED DRDMI-H-78-1-VOL-4 NL

4 OF 6
AD
A071360

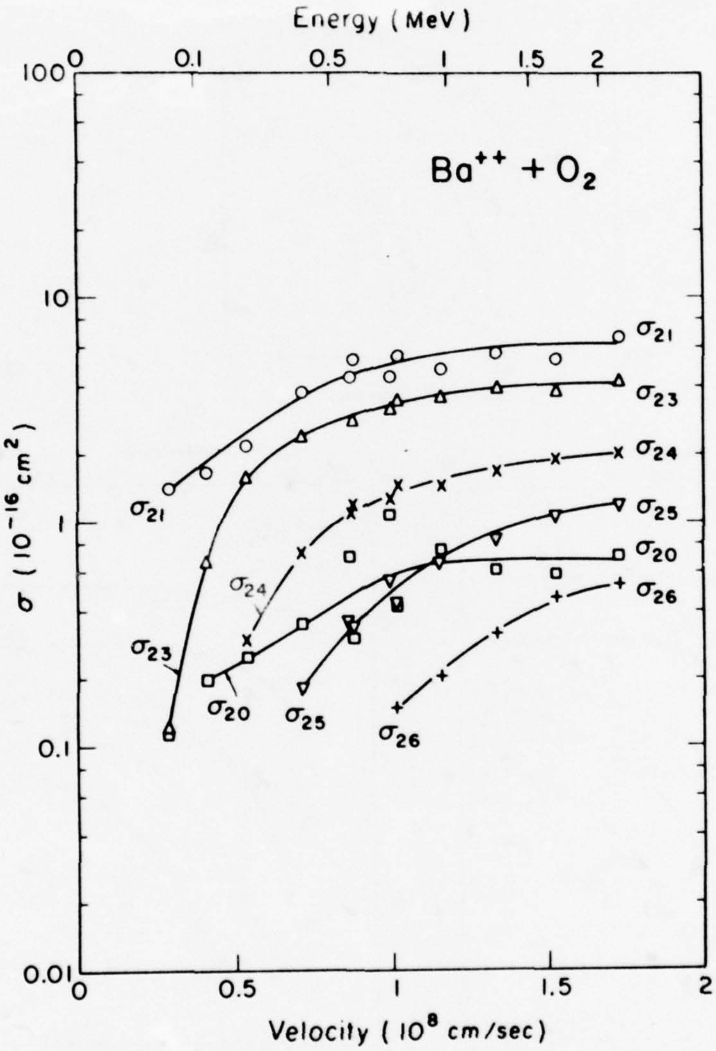



1·0
2·8
2·5
3·15
2·2
3·5
2·0
1·1
4·0
1·8
1·25
1·4
1·6
NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

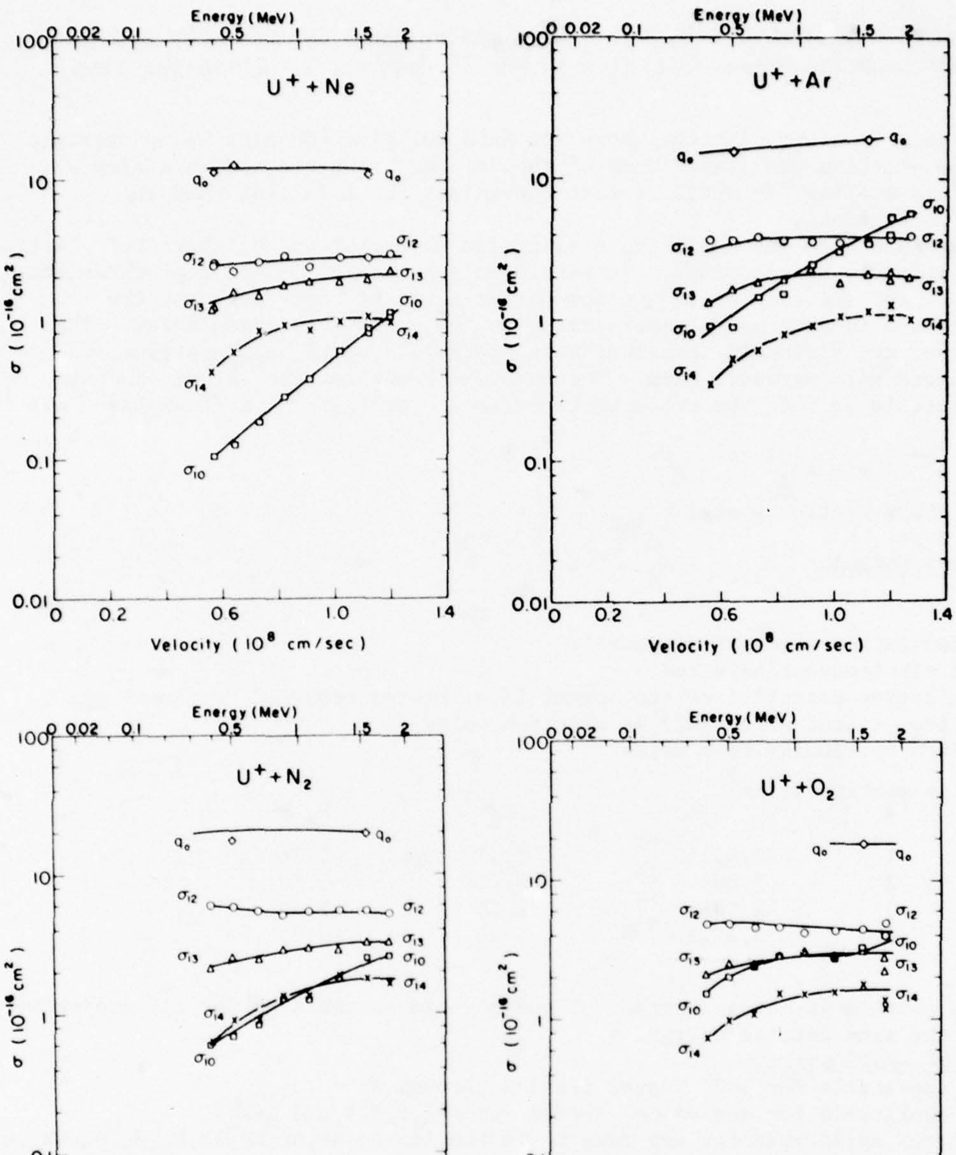
$Ba^{2+} + O_2 \rightarrow Ba^{o}$ symbol σ_{20}

$O_2 \rightarrow Ba^{+}$ symbol σ_{21}

$O_2 \rightarrow Ba^{n+}$ $(n > 2)$ symbol σ_{2n}



Graphical Data B-2.104. Electron capture and loss for Ba^{2+} in O_2.



Graphical Data B-2.105. Electron capture and loss for U^+ in Ne, Ar, N_2, O_2.

Algebraic Expression B-2.106. Electron capture by multiply charged heavy ions at impact energies below 25 keV/amu — A scaling law.

There is only a very limited amount of data for electron pick up by multiply charged ions at these energies. Much of the data can be expressed in a simple semi-empirical scaling law which is more convenient for modelling than the individual data points.

We reproduce here the empirical scaling law by Muller and Salzborn for electron capture by multiply charged ions. To within an accuracy of 35% it reproduces some two thirds of 268 separate cross section measurements by these authors, the measurements are in some seven papers cited in the references given below. The cross sections are virtually invariant with energy and quite uninteresting; we shall therefore not reproduce them. Moreover the cross section is independent of the projectile so that the cross sections for Ne^{i+}, Ar^{i+}, Kr^{i+} and Xe^{i+} are the same.

Reaction $A^{i+} + B \rightarrow A^{(i-k)+} + B^{k+}$

cross section symbol $\sigma_{i,i-k}$

Cross Section Formula $\sigma_{i,i-k} = A_k \, i^{\alpha_k} \, I^{\beta_k}$

where:

i=Initial ionization state of projectile

k=Number of electrons transferred

I=First ionization potential of the target (i.e. energy required to remove one electron from a neutral target) in electron volts.

A_k, α_k, β_k given in tabular form below

$\sigma_{i,i-k}$= cross section in cm^2

k	A_k	α_k	β_k
1	1.43×10^{-12}	1.17	-2.76
2	1.08×10^{-12}	0.71	-2.80
3	5.50×10^{-14}	2.10	-2.89
4	3.57×10^{-16}	4.20	-3.03

Note: Cross section is not a function of energy, and is the same for all projectiles species of the same initial charge.

Conditions of Applicability

i-Believed applicable for $i \geq 2$. Tested for i=2 through 8

k-Believed applicable for any value. Tested for k=1,2,3,4 and $i-k \geq 1$

Target-Believed applicable for any target. Tested for He,Ne,Ar,Kr,Xe,H_2,N_2,O_2,CH_4,CO_2

Projectile-Tested only for He,Ar,Kr, Xe. There are no data for projectiles other than the rare gas ions

Energy Range Authors suggest that this not be used above 25keV/amu. No lower limit is given but it has been tested down to 0.125 keV/amu.

Reliability-Perhaps ±35%; this is the same as the data on which it is based.

Reference-A. Muller and E. Salzborn. Proceedings of the International Conference on Low Energy Ion Beams. [Inst. Phys. Conf. Ser. 38, 169, (1978)]. A Muller and E. Salzborn, Physics Letters 62A, 391 (1977).

Tabular Data B-2.107. Electron capture and loss cross sections for heavy ions in gases at energies generally above 25 keV/amu.

Data for heavy ions in the mass range of interest are confined to Br, Kr, and I ions; they have been summarized by Betz (Rev. Mod. Phys. 44, 465 (1972) in tabular form and we reproduce that table here. It will be noted that with increasing energy the available data tend to be for the more highly charged species. At the end of the table we reproduce some of the data in graphical form; it will be observed that a given cross section does not vary greatly with the nature of the projectile or target.

The tabular data occupy the following six pages. Cross sections σ are given in units of 10^{-16} cm^2/molecule for a projectile ion of charge q colliding with a target and emerging with a carge q'. Thus when $q < q'$ the projectile has been ionized (stripped) and when $q > q'$ the projectile has picked up an electron (charge transfer). The table is in three sections, corresponding to the three projectiles and arranged in order of increasing energy with each target handled separately; within a given energy-target block the data are arranged in order of increasing initial charge q and increasing number of transfered electrons $n = q - q'$. The reference letters identify the original source of the data.

These tables include data from a number of authors and where comparisons are possible they do not always agree. In general data for one electron transfer ($q - q' = \pm 1$) are reasonably consistent while data for multiple electron transfer may differ by a factor of two between authors.

A limited part of this data compendium is displayed in figures following the table to indicate data trends.

Original References

a. N.B. Angert, A. Moller and Ch. Schmelzer, Phys. Letts. 27A, 28 (1968); A. Moller, W. Angert, B. Franzke and C.H. Schmelzer, Phys. Letts. 27A, 621 (1968); also private communications to Betz.

b. H.D. Betz, G. Ryding, A.B. Wittkower, Phys. Rev. A3, 197 (1971).

c. H.D. Betz, and A.B. Wittkower, Phys. Rev. A6, 1485 (1972).

e. S.H. Datz et al., Phys. Rev. A2, 430 (1970).

f. C.D. Moak et al., Phys. Rev, Letters 18, 41 (1967).

g. I.S. Dmitriev et al., zh. Eksperim. i Teor. Fiz. 42, 16 (1962) I Sov. Phys. JETP 15, 11 (1962)].

j. C.D. Moak et al., Phys. Rev. 176, 427 (1968).

k. V.S. Nikolaev et al. Zh. Eksperim i Teor. Fiz 40, 989 (1961) [Sov. Phys. JETP 13, 695 (1961)].

l. V.S. Nikolaev et al. Zh. Eksperim i Teor Fiz 41, 89 (1961) [Sov. Phys. JETP 14, 67 (1962)].

m. G. Ryding et al., Phys. Rev. 184, 93 (1969).

n. A. B. Wittkower and H.D. Betz, J. Phys. B4, 1173 (1971).

o. G. Ryding et al., Phys. Rev. A3, 1658 (1971).

p. B. Franzke et al., IEEE NS-19, No.2 266 (1972).

Tabular Data B-2.107. Electron capture and loss cross sections for heavy ions in gases at energies generally above 25 keV/amu (Continued).

Z=35 m=79 Br Projectiles

q	q'	σ	Ref.
6.00 MeV, HE			
2	1	1.080	b
3	2	2.580	b
4	3	5.140	b
5	4	7.120	b
6	5	9.970	b
7	6	9.300	b
8	7	13.000	b
9	8	16.600	b
3	1	0.033	b
4	2	0.159	b
5	3	0.392	b
6	4	0.684	b
7	5	0.740	b
8	6	0.310	b
9	7	0.250	b
2	3	1.980	b
3	4	1.250	b
4	5	0.832	b
5	6	0.442	b
6	7	0.230	b
7	8	0.124	b
8	9	0.040	b
9	10	0.025	b
2	4	0.445	b
3	5	0.313	b
6	8	0.022	b
2	5	0.160	b
10.00 MeV, HE			
3	2	0.898	b
4	3	1.970	b
5	4	3.380	b
6	5	5.530	b
7	6	5.160	b
8	7	7.680	b
9	8	10.400	b
10	9	13.400	b
5	3	0.056	b
6	4	0.104	b
7	5	0.154	b
8	6	0.086	b
3	4	1.250	b
4	5	0.854	b
5	6	0.560	b
6	7	0.320	b
7	8	0.173	b
8	9	0.106	b
9	10	0.060	b
10	11	0.038	b
3	5	0.331	b
4	6	0.195	b
5	7	0.131	b
6	8	0.048	b
13.90 MeV, H2			
6	5	3.170	e
7	6	3.110	e
8	7	5.290	e
10	9	11.100	e
6	4	0.002	e
6	7	0.326	e
7	8	0.188	e
8	9	0.122	e
10	11	0.096	e
6	8	0.031	e
7	9	0.028	e
8	10	0.029	e
13.90 MeV, HE			
6	5	3.540	e
8	7	5.220	e
10	9	11.300	e
6	4	0.690	e
8	6	0.410	e
10	8	0.292	e
6	7	0.563	e
8	9	0.220	e
10	11	0.101	e
6	8	0.093	e
8	10	0.049	e
6	9	0.041	e
13.90 MeV, AR			
6	5	7.490	e
8	7	12.200	e
10	9	20.800	e
6	4	0.239	e
8	6	0.127	e
10	8	0.857	e
6	7	1.150	e
8	9	0.416	e
10	11	0.363	e
6	8	0.432	e
8	10	0.401	e
6	9	0.238	e
14.00 MeV, H2			
4	3	0.640	b
5	4	1.220	b
6	5	2.660	b
7	6	2.740	b
8	7	4.190	b
6	4	0.007	b
7	5	0.016	b
8	6	0.006	b
4	5	0.740	b
5	6	0.450	b
6	7	0.286	b
7	8	0.162	b
8	9	0.118	b
4	6	0.130	b
5	7	0.075	b
6	8	0.021	b
7	9	0.010	b
8	10	0.009	b
4	7	0.027	b
4	8	0.004	b
14.00 MeV, HE			
4	3	0.738	b
5	4	1.390	b
6	5	2.740	b
7	6	3.140	b
8	7	4.450	b
9	8	6.110	b
10	9	8.180	b
7	5	0.038	b
9	7	0.037	b
10	8	0.022	b
4	5	0.819	b
5	6	0.555	b
6	7	0.429	b
7	8	0.228	b
8	9	0.166	b
9	10	0.111	b
4	6	0.195	b

Tabular Data B-2.107. Electron capture and loss cross sections for heavy ions in gases at energies generally above 25 keV/amu (Continued).

q	q'	σ	Ref.
5	7	0.155	b
6	8	0.037	b
7	9	0.019	b
	25.00 MeV, H2		
7	6	0.298	e
8	7	0.559	e
9	8	0.923	e
10	9	1.370	e
11	10	2.130	e
7	8	0.278	e
8	9	0.197	e
9	10	0.128	e
10	11	0.106	e
11	12	0.082	e
7	9	0.021	e
8	10	0.010	e
9	11	0.018	e
10	12	0.015	e
11	13	0.020	e
7	10	0.001	e
9	12	0.016	e
	25.00 MeV, HE		
7	6	0.586	e
8	1	7.120	e
9	8	1.850	e
11	10	3.610	e
7	8	0.365	e
8	9	0.303	e
9	10	0.206	e
11	12	0.164	e
7	9	0.087	e
8	10	0.081	e
9	11	0.042	e
11	13	0.074	e
7	10	0.024	e
9	12	0.024	e
	25.00 MeV, AR		
7	6	1.250	e
9	8	4.150	e
7	8	0.921	e
9	10	0.564	e
7	9	0.364	e
9	11	0.373	e
7	10	0.220	e
7	11	0.136	e
	41.67 MeV, H2		
7	6	0.021	f
8	7	0.054	f
7	8	0.287	f
8	9	0.247	f
7	9	0.021	f
8	10	0.025	f
7	10	0.002	f
8	11	0.011	f
	41.67 MeV, AR		
7	6	0.099	f
8	7	0.203	f

q	q'	σ	Ref.
7	8	0.929	f
8	9	0.056	f
7	9	0.302	f
8	10	0.289	f
7	10	0.197	f
8	11	0.180	f
7	11	0.126	f
8	12	0.152	f
7	12	0.106	f
8	13	0.098	f
7	13	0.073	f
8	14	0.072	f
7	14	0.052	f
8	15	0.370	f
7	15	0.031	f
Z=36 m=84 Kr Projectiles			
	2.97 MeV, HE		
3	2	4.000	k
4	3	6.800	k
3	4	1.130	g
4	5	0.580	g
	2.97 MeV, KR		
3	2	21.500	k
4	3	30.300	k
3	1	2.400	l
4	2	4.200	l
	2.97 MeV, N2		
3	2	12.600	k
4	3	18.600	k
3	1	1.300	l
4	2	2.940	l
3	4	2.080	g
4	5	1.320	g
Z=53 m=127 I Projectiles			
	4.50 MeV, H2		
1	0	1.220	m
2	1	5.060	m
3	2	11.800	m
4	3	17.100	m
3	1	0.312	m
4	2	1.060	m
1	2	5.170	m
2	3	3.330	m
3	4	1.690	m
4	5	1.110	m
1	3	1.600	m
2	4	1.060	m
3	5	0.484	m
1	4	0.484	m
	5.00 MeV, H2		
2	1	3.540	c
3	2	9.390	c
4	3	14.600	c
5	4	18.000	c
6	5	20.800	c

q	q'	σ	Ref.
7	6	18.500	c
8	7	22.000	c
9	8	31.000	c
10	9	36.000	c
11	10	41.000	c
12	11	47.000	c
13	12	53.000	c
14	13	67.000	c
15	14	85.000	c
2	0	0.025	c
3	1	0.256	c
4	3	0.801	c
5	3	1.990	c
6	4	1.650	c
7	5	1.190	c
2	3	2.740	c
3	4	1.650	c
4	5	0.965	c
5	6	0.345	c
6	7	0.197	c
7	8	0.044	c
2	4	0.700	c
3	5	0.266	c
4	6	0.104	c
5	7	0.023	c
6	8	0.019	c
2	5	0.136	c
4	7	0.019	c
	5.00 MeV, O2		
2	1	2.860	c
3	2	8.330	c
4	3	14.100	c
5	4	17.100	c
6	5	20.300	c
7	6	16.700	c
8	7	30.000	c
9	8	34.000	c
10	9	40.000	c
11	10	44.000	c
12	11	51.000	c
13	12	62.000	c
14	13	81.000	c
3	1	0.219	c
4	2	1.150	c
5	3	2.800	c
6	4	3.950	c
7	5	6.140	c
2	3	3.620	c
3	4	2.730	c
4	5	1.860	c
5	6	1.010	c
6	7	0.764	c
7	8	0.511	c
2	4	1.620	c
3	5	1.460	c
4	6	1.060	c
5	7	0.545	c
6	8	0.321	c
7	9	0.189	c

Tabular Data B-2.107. Electron capture and loss cross sections for heavy ions in gases at energies generally above 25 keV/amu (Continued).

q	q'	σ	Ref.
2	5	1.02	c
3	6	1.010	c
4	7	0.776	c
5	8	0.184	c
6	9	0.124	c
3	7	0.247	c
6.00 MeV, HE			
2	1	1.120	b
3	2	3.460	b
4	3	6.760	b
5	4	9.330	b
6	5	10.500	b
7	6	10.400	b
8	7	13.400	b
9	8	17.700	b
4	2	0.057	b
5	3	0.273	b
6	4	0.418	b
7	5	0.811	b
8	6	0.640	b
9	7	0.910	b
2	3	2.600	b
3	4	1.500	b
4	5	1.270	b
5	6	0.761	b
6	7	0.587	b
7	8	0.294	b
8	9	0.168	b
9	10	0.034	b
2	4	0.983	b
3	5	0.732	b
4	6	0.321	b
5	7	0.211	b
6	8	0.078	b
2	5	0.492	b
3	6	0.239	b
4	7	0.110	b
2	6	0.153	b
9.50 MeV CO2			
3	2	4.500	p
4	3	10.200	p
5	4	14.000	p
6	5	18.500	p
7	6	21.500	p
8	7	25.000	p
2	3	6.600	p
3	4	5.400	p
4	5	4.500	p
5	6	2.800	p
6	7	2.600	p
7	8	1.600	p
8	9	1.250	p
2	4	3.400	p
3	5	2.900	p
4	6	2.400	p
5	7	1.600	p
6	8	1.400	p
7	9	0.700	p
2	5	1.900	p
3	6	1.400	p
4	7	2.200	p
5	8	1.100	p
6	9	0.900	p
10.00 MeV, H2			
3	2	3.210	c
4	3	5.990	c
5	4	9.080	c
6	5	13.700	c
7	6	18.100	c
8	7	18.300	c
10	9	27.000	c
11	10	31.000	c
12	11	36.000	c
13	12	41.000	c
14	13	53.000	c
15	14	62.000	c
16	15	72.000	c
17	16	88.000	c
18	17	99.000	c
9	8	24.000	c
3	1	0.144	c
4	2	0.300	c
5	3	0.499	c
6	4	0.735	c
7	5	1.06	c
8	6	0.272	c
3	4	1.890	c
4	5	1.320	c
5	6	0.807	c
6	7	0.724	c
7	8	0.669	c
8	9	0.372	c
3	5	0.686	c
4	6	0.405	c
5	7	0.332	c
6	8	0.183	c
7	9	0.319	c
3	6	0.369	c
4	7	0.230	c
5	8	0.152	c
6	9	0.348	c
10.00 MeV HE			
3	2	1.980	b
4	3	4.460	b
5	4	6.280	b
6	5	7.350	b
7	6	7.710	b
8	7	10.600	b
9	8	13.000	b
4	2	0.027	b
5	3	0.117	b
6	4	0.185	b
7	5	0.511	b
8	6	0.272	b
9	7	0.500	b
3	4	1.630	b
4	5	1.340	b
5	6	0.847	b
6	7	0.744	b
7	8	0.471	b
8	9	0.336	b
9	10	0.199	b
3	5	0.717	b
4	6	0.463	b
5	7	0.349	b
6	8	0.194	b
7	9	0.124	b
3	6	0.328	b
4	7	0.180	b
5	8	0.092	b
10.00 MeV, O2			
3	2	3.240	c
4	3	6.980	c
5	4	9.950	c
6	5	14.600	c
7	6	15.100	c
8	7	20.500	c
9	8	24.100	c
10	9	30.200	c
11	10	34.000	c
12	11	40.000	c
13	12	45.000	c
14	13	59.000	c
15	14	70.000	c
16	15	77.000	c
3	1	0.062	c
4	2	0.312	c
5	3	0.738	c
6	4	1.320	c
7	5	3.160	c
8	6	3.450	c
9	7	4.050	c
10	8	6.090	c
3	4	2.690	c
4	5	2.110	c
5	6	1.400	c
6	7	1.070	c
7	8	0.700	c
8	9	0.600	c
9	10	0.414	c
3	5	1.370	c
4	6	0.992	c
5	7	0.705	c
6	8	0.366	c
7	9	0.390	c
8	10	0.220	c
9	11	0.247	c
3	6	1.010	c
4	7	0.690	c
5	8	0.397	c
6	9	0.250	c
10.00 MeV, AR			
4	3	6.740	c
4	5	2.230	c
4	6	0.879	c
4	7	0.497	c

Tabular Data B-2.107. Electron capture and loss cross sections for heavy ions in gases at energies generally above 25 keV/amu (Continued).

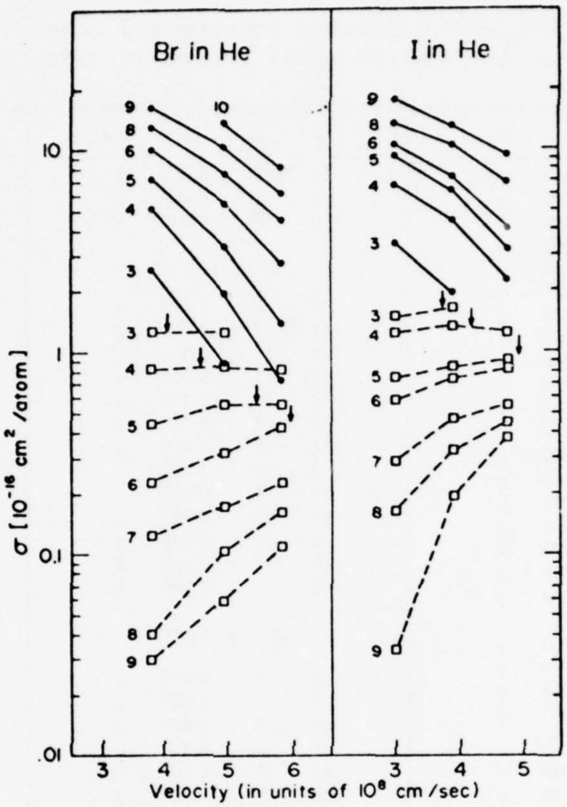
q	q'	σ	Ref.
4	8	0.233	c
4	9	0.157	c
12.00 MeV, H2			
5	4	6.390	n
5	3	9.017	n
5	6	0.716	n
5	7	0.214	n
12.00 MeV N2			
5	4	8.630	n
5	3	0.402	n
5	6	1.500	n
5	7	0.791	n
5	8	0.574	n
12.00 MeV, O2			
5	4	8.400	n
5	3	0.386	n
5	6	1.510	n
5	7	0.903	n
5	8	0.602	n
12.00 MeV, CO2			
5	4	10.300	n
5	3	0.619	n
5	6	1.870	n
5	7	1.170	n
5	8	0.888	n
12.00 MeV, N2O			
5	4	10.800	n
5	3	0.539	n
5	6	1.790	n
5	7	1.030	n
5	8	0.871	n
12.00 MeV, AIR			
9	8	26.300	o
13	12	45.500	o
15	14	62.200	o
16	15	85.200	o
17	16	73.000	o
18	17	77.000	o
12.00 MeV, CH4			
5	4	11.200	n
5	3	0.612	n
5	6	1.480	n
5	7	0.641	n
5	8	0.417	n
12.00 MeV, C1			
5	4	8.540	n
5	3	0.441	n
5	6	1.460	n
5	7	0.812	n
5	8	0.499	n
13.69 MeV, N2			
5	4	7.200	a
6	5	16.820	a
6	7	2.420	a
6	8	0.912	a
6	9	0.646	a
15.00 MeV, H2			
5	4	2.810	c
6	5	3.080	c
7	6	5.250	c
8	7	7.720	c
9	8	11.500	c
10	9	16.600	c
11	10	20.900	c
12	11	26.000	c
13	12	29.000	c
14	13	39.000	c
15	14	44.000	c
16	15	51.000	c
17	16	60.000	c
6	4	0.134	c
7	5	0.040	c
8	6	0.287	c
9	7	0.095	c
10	8	0.298	c
5	6	0.778	c
6	7	0.703	c
7	8	0.391	c
8	9	0.221	c
9	10	0.140	c
10	11	0.106	c
5	7	0.201	c
6	8	0.172	c
7	9	0.099	c
8	10	0.064	c
5	8	0.041	c
15.00 MeV, HE			
4	3	2.260	b
5	4	3.210	b
6	5	4.020	b
7	6	5.590	b
8	7	7.410	b
9	8	9.390	b
10	9	12.200	b
6	4	0.044	b
7	5	0.240	b
8	6	0.063	b
9	7	0.163	b
10	8	0.282	b
4	5	1.240	b
5	6	0.906	b
6	7	0.837	b
7	8	0.545	b
8	9	0.452	b
9	10	0.386	b
10	11	0.258	b
4	6	0.483	b
5	7	0.437	b
6	8	0.278	b
4	7	0.275	b
5	8	0.152	b
15.00 MeV, O2			
5	4	5.800	c
6	5	7.710	c
7	6	10.700	c
8	7	13.400	c
9	8	16.100	c
10	9	21.500	c
11	10	24.400	c
12	11	28.000	c
13	12	32.000	c
14	13	40.000	c
15	14	45.000	c
16	15	55.000	c
17	16	63.000	c
18	17	72.000	c
5	3	0.222	c
6	4	0.332	c
7	5	1.230	c
8	6	0.685	c
9	7	1.600	c
10	8	3.310	c
11	9	5.220	c
5	6	1.730	c
6	7	1.430	c
7	8	0.889	c
8	9	0.774	c
9	10	0.583	c
10	11	0.444	c
11	12	0.415	c
5	7	1.020	c
6	8	0.662	c
7	9	0.487	c
8	10	0.442	c
9	11	0.316	c
10	12	0.268	c
11	13	0.245	c
5	8	0.579	c
6	9	0.413	c
7	10	0.361	c
8	11	0.349	c
9	12	0.270	c
10	13	0.199	c
5	9	0.399	c
6	10	0.356	c
7	11	0.328	c
8	12	0.236	c
9	13	0.151	c
5	10	0.362	c
6	11	0.216	c
7	12	0.227	c
8	13	0.120	c
5	11	0.303	c
6	12	0.173	c
7	13	0.147	c
5	12	0.182	c
6	13	0.074	c
5	13	0.094	c

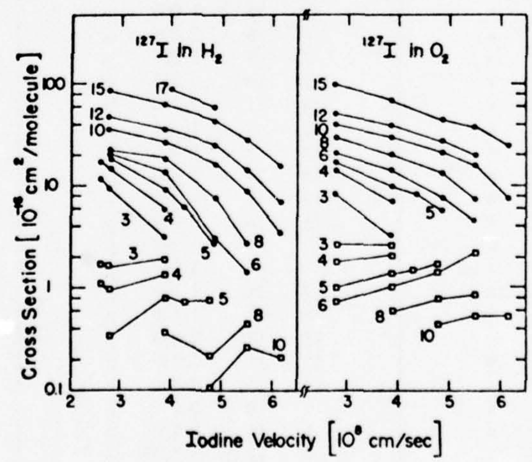
Tabular Data B-2.107. Electron capture and loss cross sections for heavy ions in gases at energies generally above 25 keV/amu (Continued).

q	q'	σ	Ref.
16.00 MeV, N2			
11	10	23.400	c
11	9	2.220	c
11	12	0.517	c
16.00 MeV, AIR			
10	9	19.500	o
11	10	23.400	o
12	11	28.000	o
13	12	36.400	o
14	13	41.500	o
15	14	44.500	o
16	15	46.500	o
17	16	47.500	o
18	17	59.600	o
19	18	57.500	o
20	19	70.800	o
21	20	61.600	o
22	21	76.000	o
18.64 MeV, N2			
6	5	8.820	a
7	6	11.840	a
8	7	19.180	a
6	7	2.580	a
7	8	1.728	a
20.00 MeV, H2			
6	5	1.490	c
7	6	1.270	c
8	7	2.790	c
9	8	6.330	c
10	9	9.000	c
12	11	14.400	c
13	12	18.000	c
14	13	25.000	c
15	14	29.000	c
16	15	35.000	c
9	7	0.150	c
6	7	0.780	c
7	8	0.560	c
8	9	0.464	c
9	10	0.267	c
10	11	0.217	c
7	9	0.052	c
9	11	0.045	c
20.00 MeV, O2			
6	5	4.580	c
7	6	5.510	c
8	7	7.520	c
9	8	13.500	c
10	9	16.000	c
12	11	20.000	c
13	12	23.500	c
14	13	33.000	c
15	14	38.000	c
16	15	43.500	c
7	5	0.100	c
8	6	0.602	c
9	7	0.803	c
6	7	2.200	c
7	8	1.050	c
8	9	0.860	c
9	10	0.659	c
10	11	0.538	c
6	8	1.120	c
7	9	0.525	c
8	10	0.316	c
9	11	0.295	c
10	12	0.260	c
7	10	0.345	c
8	11	0.255	c
9	12	0.244	c
24.36 MeV, N2			
6	5	4.860	a
7	6	5.140	a
8	7	13.740	a
9	8	14.980	a
10	9	21.200	a
6	7	2.700	a
7	8	2.140	a
8	9	1.802	a
9	10	1.542	a
10	11	1.370	a
7	9	1.016	a
8	10	0.968	a
9	11	0.920	a
7	10	0.576	a
8	11	0.306	a
9	12	0.518	a
7	11	0.348	a
8	12	0.260	a
9	13	0.478	a
24.40 MeV, CO2			
5	4	2.150	p
6	5	3.600	p
7	6	4.800	p
8	7	8.400	p
9	8	11.000	p
10	9	13.200	p
11	10	15.000	p
4	5	4.800	p
5	6	3.700	p
6	7	3.300	p
7	8	2.600	p
8	9	2.000	p
9	10	1.500	p
4	6	2.500	p
5	7	1.800	p
6	8	1.330	p
7	9	1.200	p
8	10	1.100	p
9	11	0.910	p
4	7	1.200	p
5	8	0.620	p
6	9	0.860	p
7	10	0.650	p
8	11	0.480	p
9	12	0.680	p
25.00 MeV, H2			
10	9	3.510	c
14	13	13.000	c
15	14	16.000	c
10	8	0.010	c
10	11	0.205	c
25.00 MeV, O2			
10	9	7.690	c
14	13	21.000	c
15	14	25.000	c
10	8	1.080	c
10	11	0.533	c
30.81 MeV, N2			
6	5	2.320	a
7	6	2.200	a
8	7	5.120	a
9	8	9.980	a
10	9	12.780	a
14	13	31.800	a
15	14	31.400	a
16	15	35.600	a
17	16	35.200	a
6	7	3.080	a
7	8	2.380	a
8	9	1.946	a
9	10	1.540	a
10	11	1.440	a
7	9	0.904	a
10	12	0.944	a
7	10	0.404	a
10	13	0.580	a
7	11	0.628	a
10	14	0.428	a
7	12	0.410	a
38.04 MeV, N2			
8	7	2.200	a
9	8	5.200	a
10	9	9.660	a
11	10	9.880	a
10	8	0.130	a
8	9	2.360	a
9	10	2.260	a
10	11	1.562	a
10	12	0.906	a
10	13	0.750	a
10	14	0.442	a
10	15	0.248	a
38.10 MeV, CO2			
6	5	0.830	p
7	6	1.050	p
8	7	2.230	p
9	8	4.050	p

Tabular Data B-2.107. Electron capture and loss cross sections for heavy ions in gases at energies generally above 25 keV/amu (Concluded).

q	q'	σ	Ref.
10	9	6.600	p
11	10	9.600	p
12	11	11.200	p
13	12	12.500	p
5	6	4.750	p
6	7	4.000	p
7	8	3.150	p
8	9	2.500	p
9	10	2.100	p
10	11	1.500	p
11	12	1.150	p
5	7	2.390	p
6	8	1.900	p
7	9	1.350	p
8	10	1.000	p
9	11	1.050	p
10	12	0.930	p
11	13	0.540	p
5	8	1.160	p
6	9	0.960	p
7	10	0.830	p
8	11	0.740	p
10	13	0.310	p
11	14	0.450	p
46.03 MeV, N2			
9	8	3.140	a
10	9	5.300	a
11	10	7.480	a
12	11	10.640	a
9	7	0.084	a
10	8	0.048	a
12	10	0.186	a
9	10	1.804	a
10	11	1.328	a
11	12	1.830	a
12	13	1.404	a
9	11	1.184	a
10	12	0.890	a
11	13	0.420	a
12	14	0.448	a
9	12	0.694	a
10	13	0.628	a
11	14	0.708	a
12	15	0.326	a
9	13	0.312	a
10	14	0.262	a
11	15	0.422	a
12	16	0.214	a
9	14	0.080	a
10	15	0.118	a
11	16	0.206	a
9	15	0.044	a
10	16	0.048	a
54.78 MeV, N2			
10	9	2.220	a
11	10	3.560	a
12	11	5.480	a
13	12	8.940	a
17	16	13.540	a
18	17	15.580	a
11	12	2.080	a
12	13	1.624	a
12	14	0.978	a
12	15	0.582	a
12	16	0.330	a
12	17	0.148	a
12	18	0.050	a
54.80 MeV, CO2			
8	7	0.660	p
9	8	1.420	p
10	9	2.450	p
11	10	3.350	p
12	11	5.000	p
13	12	7.000	p
14	13	8.800	p
15	14	10.100	p
16	15	11.000	p
7	8	3.800	p
8	9	3.300	p
9	10	2.850	p
10	11	2.400	p
11	12	1.930	p
12	13	1.600	p
13	14	1.380	p
14	15	1.100	p
15	16	0.940	p
7	9	1.950	p
8	10	1.600	p
9	11	1.490	p
10	12	1.100	p
11	13	0.850	p
12	14	0.720	p
13	15	0.480	p
7	10	0.980	p
8	11	0.830	p
9	12	0.700	p
10	13	0.850	p
11	14	0.780	p
12	15	0.480	p
64.28 MeV, N2			
12	11	3.680	a
13	12	4.440	a
13	14	1.484	a
110.00 MeV, H2			
12	11	0.016	j
12	13	0.100	j
12	14	0.380	j
12	15	0.010	j
12	16	0.003	j
110.00 MeV, HE			
12	11	0.065	j
12	13	0.160	j
12	14	0.060	j
12	15	0.020	j
12	16	0.007	j
12	17	0.004	j
110.00 MeV, AR			
12	11	0.090	j
12	13	0.700	j
12	14	0.400	j
12	15	0.180	j
12	16	0.120	j
12	17	0.070	j
12	18	0.050	j
12	19	0.037	j
12	20	0.030	j
12	21	0.024	j
12	22	0.020	j
12	23	0.014	j
12	24	0.011	j
162.00 MeV, O2			
17	18	0.600	j
17	19	0.200	j
17	20	0.120	j
17	21	0.080	j
17	22	0.060	j
17	23	0.040	j
17	24	0.022	j
17	25	0.010	j
17	26	0.002	j



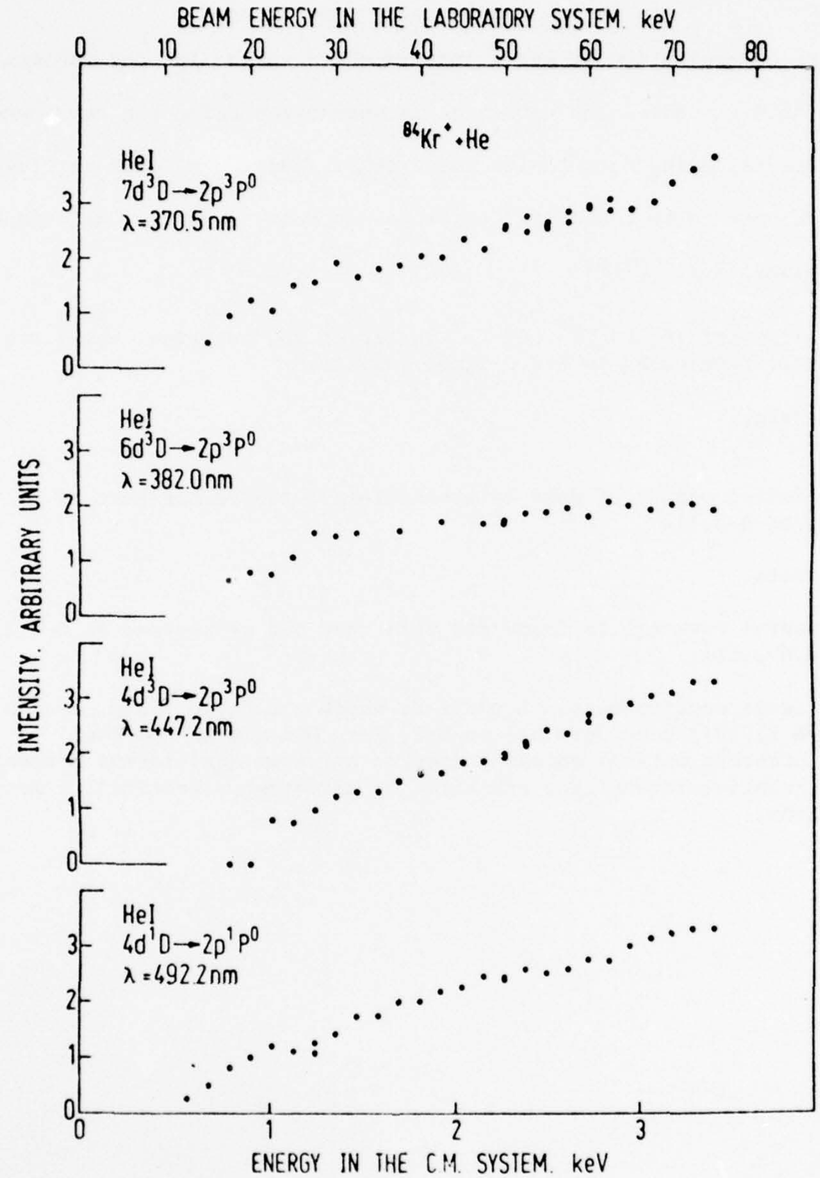


Graphical Data B-2.108. Velocity dependence of cross sections for capture (full symbols) and loss (open symbols) of a single electron by Br and I ions in He, H_2 and O_2; drawn from the preceding table. The initial charge state is shown by each curve. The data were taken from H. Betz, Rev. Mod. Phys. 44, 465 (1972).

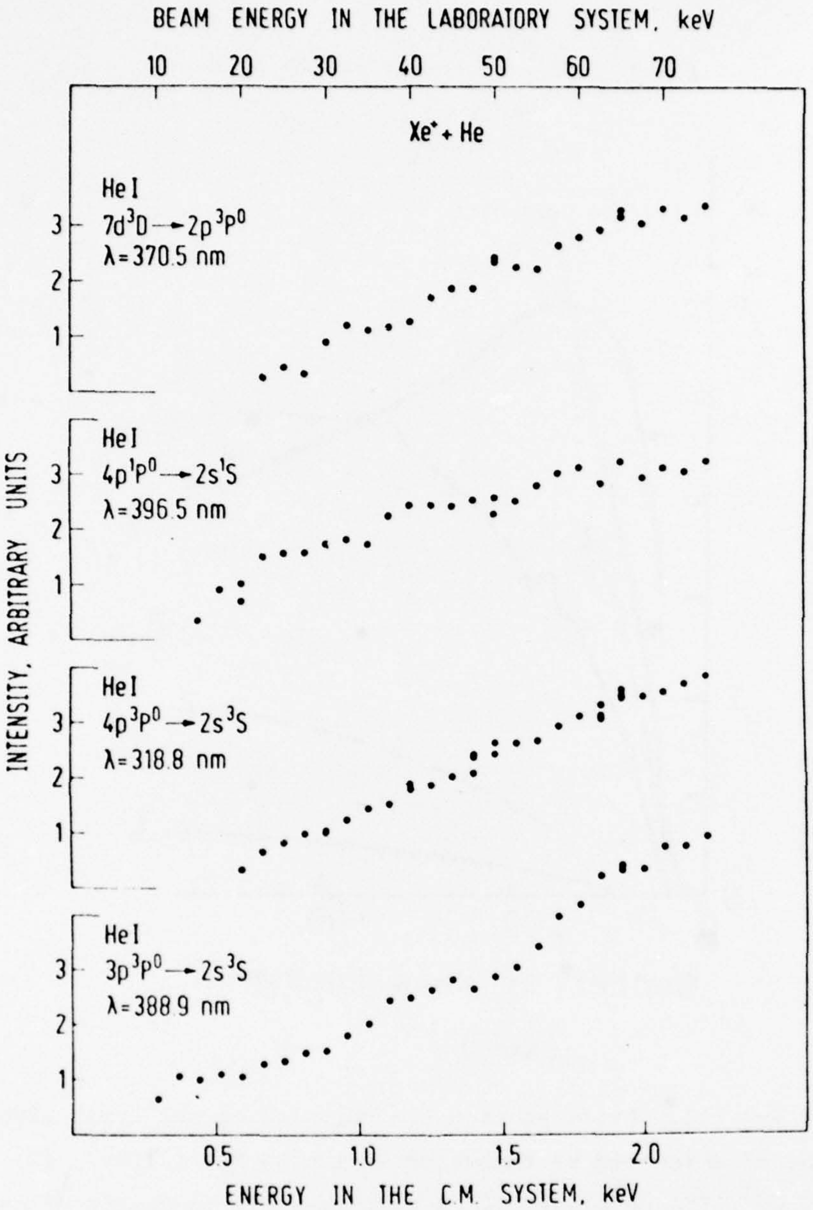
Data Source Listing B-2.109. Excitation of gases by heavy ion impact.

The literature on excitation by heavy ions is quite sparse for the projectiles of interest here (32 < Z < 65). The situation is summarized below and representative data are given in the following data tables and graphs. Additional data for lower Z projectiles (Z < 32) are to be found in "Excitation in Heavy Particle Collisions" by E. W. Thomas (Wiley, N.Y., 1972).

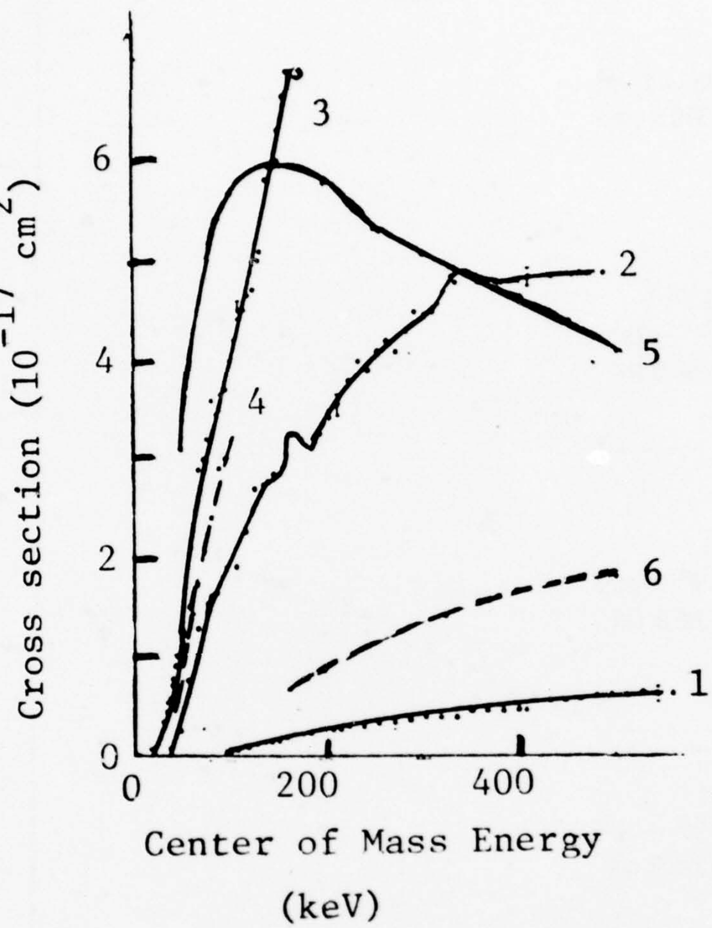
He Target	Data restricted to Kr^+ and Xe^+ impact at low energies; these are partly reproduced as B-2.110 and B-2.111.
Ne, Ar, Kr, Xe Targets	No data.
H_2 Target	A limited amount of data is available and reproduced here as figure B-2.112
O_2 Target	No data.
N_2 Target	A useful coverage is found for this case and reproduced as B-2.113 and B-2.114.
Other Molecules	No cross section data. A paper by Haugh and Bayes (Phys. Rev. A 2, 1778 (1970)) considers Ar^+ on N_2O, HBr, HCℓ and Kr^+ on HBr; it presents optical emission spectra and some qualitative discussion of relative intensities exhibited by different vibrational transitions.



Graphical Data B-2.110. Intensity (in arbitrary units) of certain He I lines excited by Kr^+ impact on He. Note energy given both in laboratory and center of mass frames. The data were taken from E. Veje, University of Copenhagen, Private Communication.

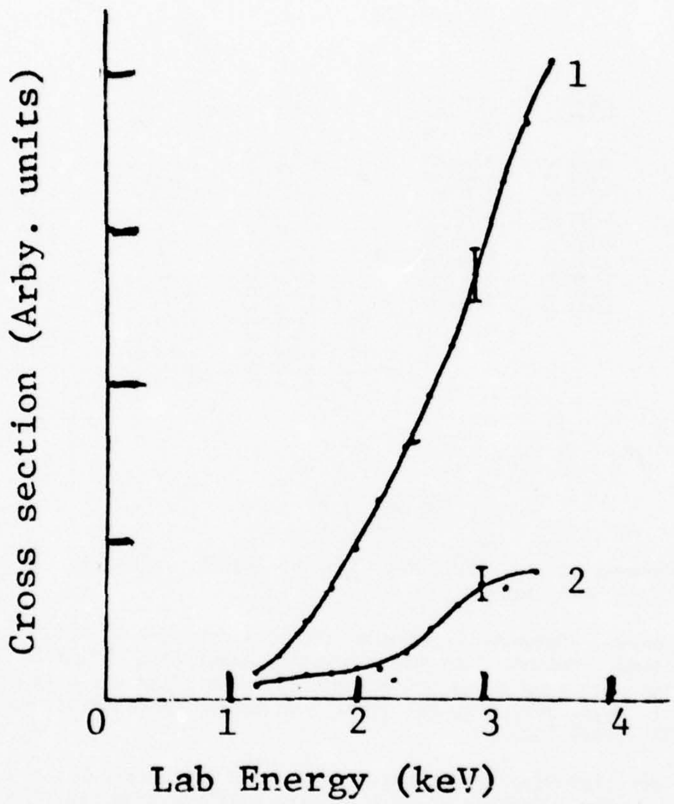


Graphical Data B-2.111. Intensity (in arbitrary units) of certain He I lines excited by Xe^+ impact on He. Note energy given in both laboratory and center of mass frames. The data were taken from E. Veje, University of Copenhagen, Private Communication.



Graphical Data B-2.112. Cross section for emission of the Lyman alpha (1216 Å) line of H induced by impact of an ion on H_2; (1) Na^+, (2) K^+, (3) Rb^+, (4) Cs^+, (5) He^+, (6) H^+. Energy is given in center of mass frame of reference.

Reference: S. Bobashev, "Electronic and Atomic Collisions" (Abstracts of Papers VIII ICPEAC, Belgrade 1973) (Institute of Physics, Belgrade) page 665.



Graphical Data B-2.113. Cross section for excitation of the 2p (1) and 2s (2) states of H due to Cs^+ impact on H_2. Energy given in lab frame of reference.

Reference: S. Bobashev, "Electronic and Atomic Collisions" (Abstracts of Papers VIII ICPEAC, Belgrade 1973) (Institute of Physics, Belgrade) page 665.

Tabular Data B-2.114. Cross sections for emission of the N_2^+ 3914 Å transition ($B\ ^2\Sigma_u^+ \rightarrow X\ ^2\Sigma_g^+$ (0,0)) induced by heavy ion impact on N_2.

$$X^+ + N_2 \rightarrow (X^+ + e) + N_2^{+*}$$

$$N_2^{+*} \rightarrow N_2^+ + h\nu\ (3914\ \text{Å}).$$

<u>Projectile</u>

N^+

ENERGY (KEV)	CROSS SECTION (SQ. CM)
3.20E 01	1.21E-16
6.80E 01	1.23E-16
9.10E 01	1.25E-16
1.29E 02	1.24E-16
1.48E 02	1.25E-16
1.81E 02	1.21E-16
2.19E 02	1.22E-16
2.68E 02	1.21E-16
2.74E 02	1.06E-16
3.44E 02	1.24E-16
3.54E 02	1.15E-16
3.70E 02	1.11E-16
4.33E 02	9.39E-17
5.44E 02	9.12E-17
6.71E 02	8.80E-17
8.25E 02	7.80E-17
1.01E 03	7.95E-17
1.23E 03	7.10E-17
1.49E 03	6.10E-17
1.76E 03	6.39E-17
1.97E 03	5.85E-17

Xe^+

ENERGY (KEV)	CROSS SECTION (SQ. CM)
2.74E 02	5.00E-17
3.80E 02	5.60E-17
4.85E 02	6.33E-17
5.92E 02	6.72E-17
7.50E 02	7.12E-17
9.62E 02	8.20E-17
1.18E 03	7.70E-17
1.44E 03	8.19E-17
1.65E 03	8.64E-17
1.81E 03	8.59E-17

Ba^+

ENERGY (KEV)	CROSS SECTION (SQ. CM)
3.28E 02	3.82E-17
4.02E 02	3.59E-17
4.34E 02	3.59E-17
5.28E 02	3.59E-17
7.08E 02	4.20E-17
7.52E 02	3.74E-17
8.73E 02	4.95E-17
1.08E 03	5.45E-17
1.23E 03	6.15E-17
1.32E 03	6.25E-17
1.43E 03	7.15E-17
1.58E 03	7.80E-17
1.75E 03	8.94E-17
1.95E 03	1.05E-16
2.05E 03	1.15E-16
2.13E 03	1.10E-16

Ba^{2+}

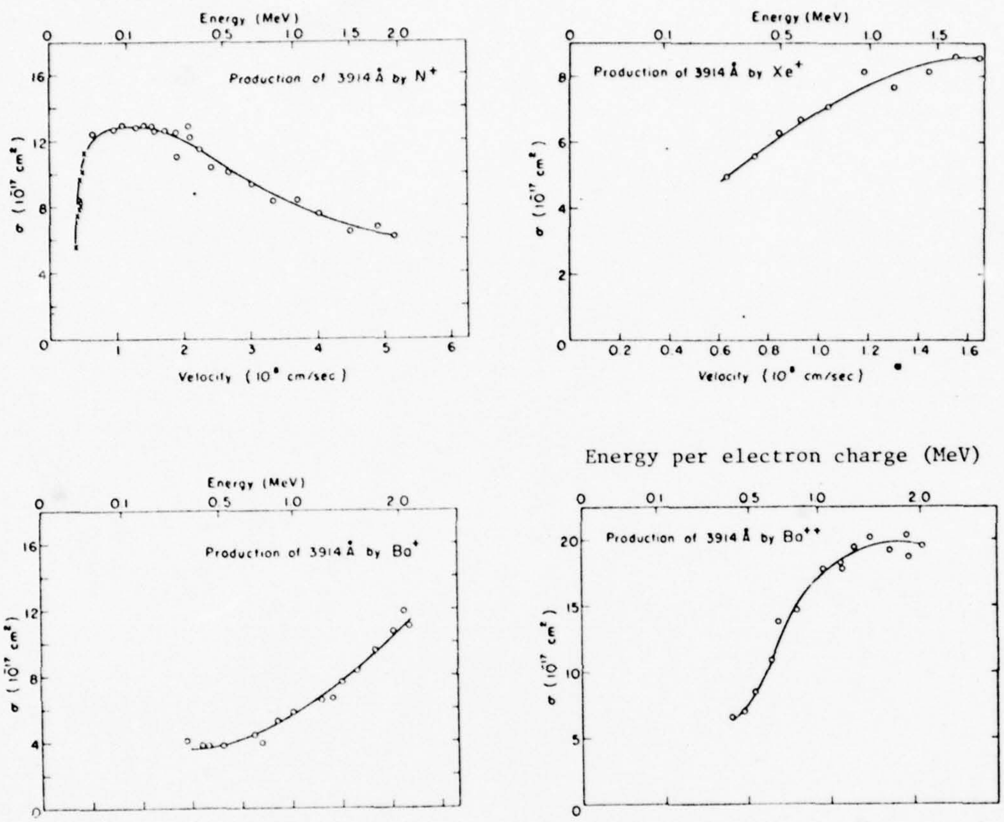
ENERGY (KEV)	CROSS SECTION (SQ. CM)
8.04E 02	6.15E-17
9.52E 02	6.65E-17
1.08E 03	8.40E-17
1.29E 03	1.00E-16
1.50E 03	1.29E-16
1.67E 03	1.37E-16
2.10E 03	1.66E-16
2.42E 03	1.72E-16
2.44E 03	1.66E-16
2.67E 03	1.82E-16
2.98E 03	1.88E-16
3.41E 03	1.80E-16
3.79E 03	1.90E-16
3.83E 03	1.74E-16
4.16E 03	1.83E-16

<u>Reference</u>: L. Kurzweg et al., Phys. Rev. <u>179</u>, 55 (1969). Also Erratum in Phys. Rev. <u>185</u>, 404 (1969).

Note: (i) The above referenced paper also includes data for O^+ and N_2^+ projectiles. Further data for moderately heavy ions (F^+, Ne^+, Na^+, Rb^+ at energies from 30 to 100 keV are to be found in the work of Hoffman et al; Phys. Rev. A <u>9</u>, 187 (1974) and Sandia Laboratories Report SC-RR-70-695 (1970).

(ii) The spectral line considered here is only one of the First Negative Band System. Various studies suggest that the cross sections for other lines, and for level excitation, can be estimated by the use of theoretical transition probabilities as discussed earlier in Scaling Law B-2.46.

(iii) Some separate studies of the apparent "rotational temperature" of excited N_2^+ induced by Kr^+, Rb^+, Xe^+ and Cs^+ impact are to be found in the work of Polyakova et al., Soviet Physics JETP <u>30</u>, 63 (1970) and Lowe, "Fourth International Conf. on the Physics of Electronic and Atomic Collisions", Quebec 1965 (Science Bookcrafters N.Y. 1965) page 285.



Graphical Data B-2.115. Cross sections for collisionally induced emission of the 3914 Å N_2^+ line by N^+, Xe^+, Ba^+, and Ba^{2+} impact on N_2. For tabular data and reference see preceding page.

C. ELECTRON-HEAVY PARTICLE COLLISIONS

CONTENTS

C-1. ELECTRON SCATTERING: ELASTIC, TOTAL, AND MOMENTUM TRANSFER

CONTENTS

Page

Page

General Reference:

Y. Itikawa, "Momentum-Transfer Cross Sections for Electron Collisions with Atoms and Molecules: Revision and Supplement, 1977," Atomic Data and Nuclear Data Tables 21, 69 (1978).

Definitions of Various Kinds of Cross Sections

Total Scattering - The cross section for all scattering events, elastic and inelastic.

Momentum Transfer - A total cross section obtained by integrating the differential center-of-mass cross section over all angles weighted by the factor $(1 - \cos \theta)$. θ is the center-of-mass scattering angle. Although it is often assumed that the momentum transfer cross section is an elastic cross section, it is often derived from experimental results which include inelastic effects. Care must be taken to determine the quantities used in the derivation, as discussed in the references.

Total Elastic Scattering - The unweighted integral of the differential elastic cross section.

Total Ionization - This is, in fact, the cross section for electron production and is also defined as

$$\sigma_T = \sigma_1 + 2\sigma_2 + 3\sigma_3 + \ldots$$

The subscripts on the σ's on the right-hand side of the equation designate the individual cross sections for producing ions of positive charge indicated by the subscript.

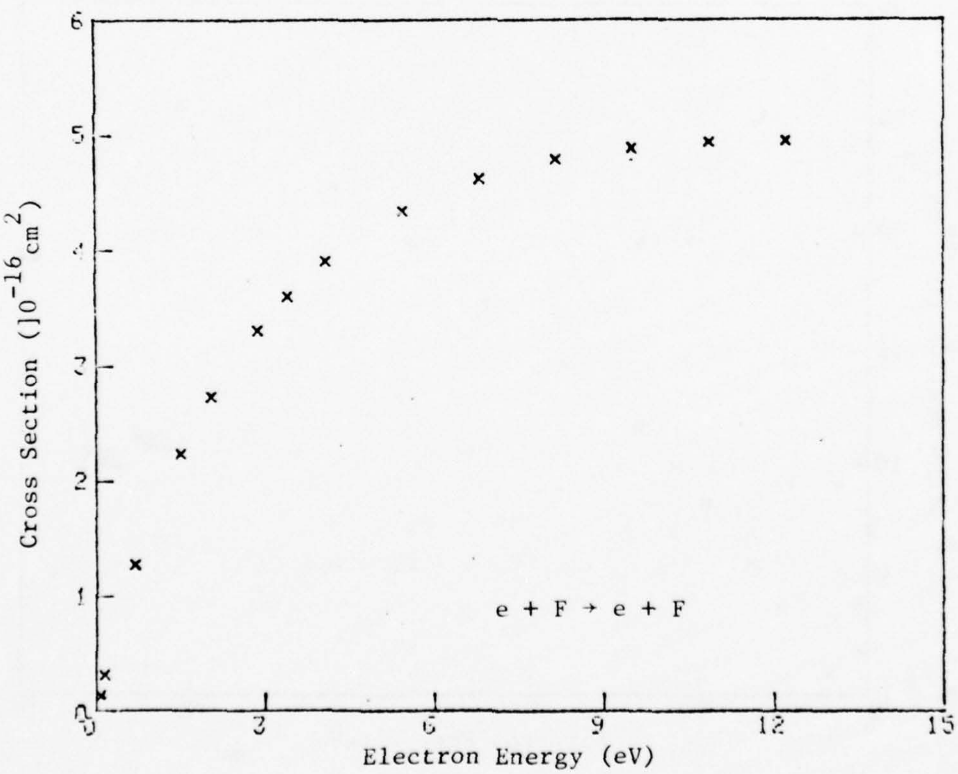
Electronic Excitation - As used here this term is the total cross section for direct excitation of the atomic or molecular level indicated, unless otherwise noted. In some cases, the cross section refers to the radiation emitted with the decay of the excited state.

Tabular and Graphical Data C-1.1 Elastic scattering cross sections for electrons in F.

e + F → e + F

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0.0680	0.149	6.80	4.63
0.136	0.314	8.16	4.80
0.680	1.28	9.52	4.90
1.50	2.24	10.9	4.95
2.04	2.73	12.2	4.96
2.86	3.30		
3.40	3.60		
4.08	3.91		
5.44	4.35		

Cont. Next Column



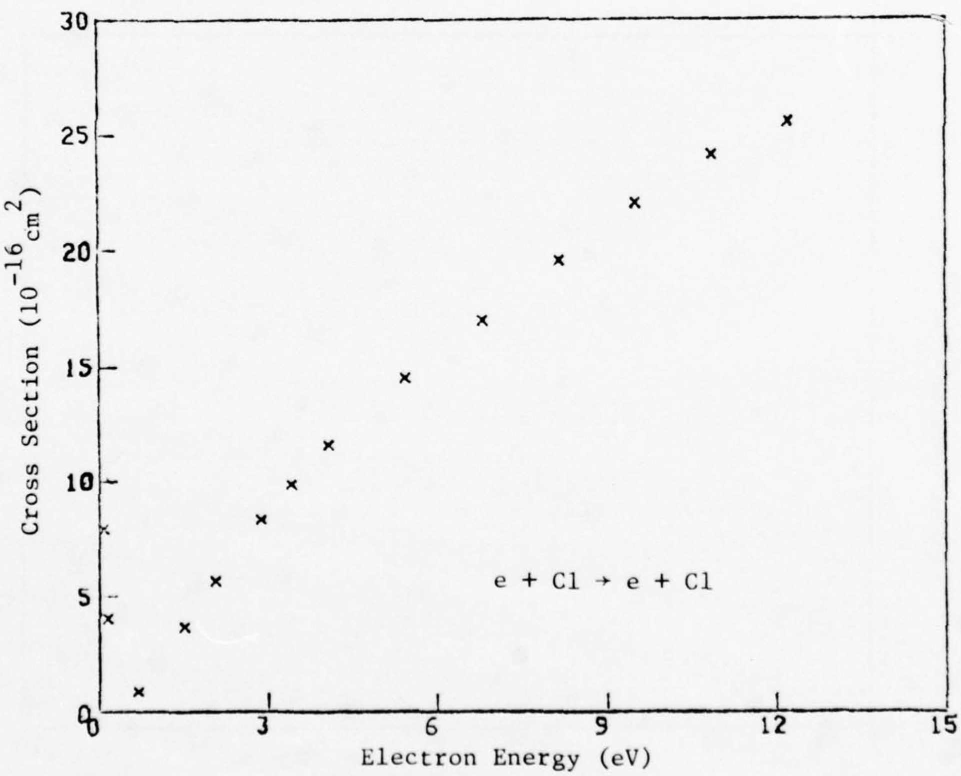
Reference: E. J. Robinson and S. Geltman, Phys. Rev. 153, 4 (1967)

Tabular and Graphical Data C-1.2a. Elastic scattering cross sections for electrons in Cl.

$e + Cl \rightarrow e + Cl$

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0.0680	7.90	5.44	14.5
0.136	4.04	6.80	17.0
0.680	0.847	8.16	19.6
1.50	3.66	9.52	22.1
2.04	5.66	10.9	24.2
2.86	8.33	12.2	25.6
3.40	9.87		
4.08	11.6		

Cont. Next Column



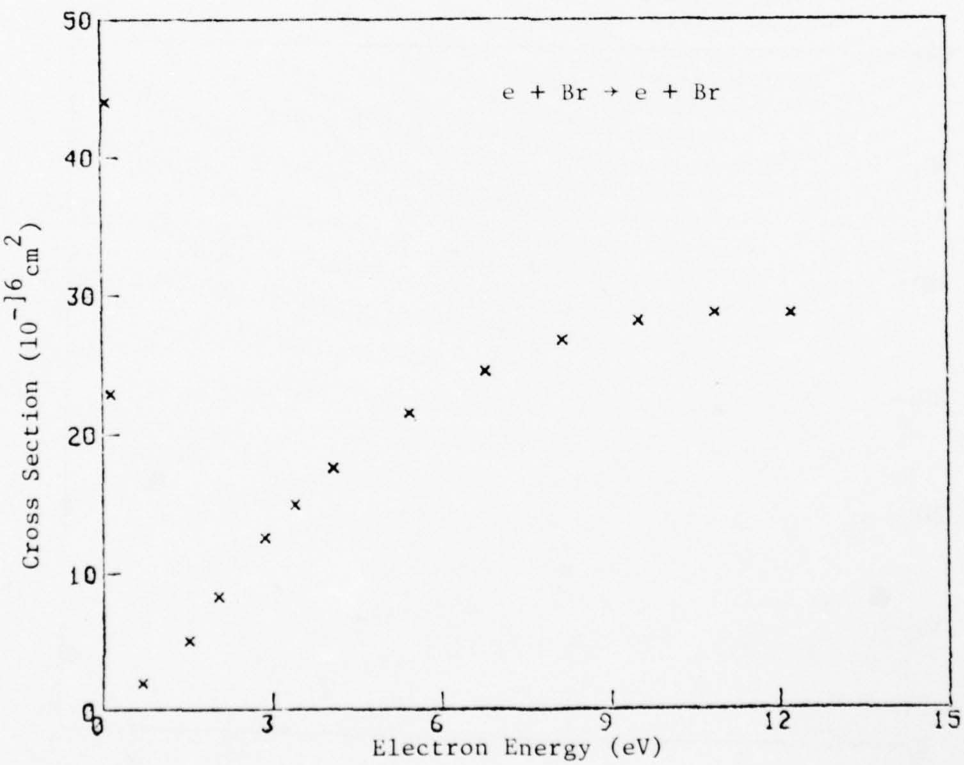
Reference: E. J. Robinson and S. Geltman, Phys. Rev. 153, 4 (1967)

Tabular and Graphical Data C-1.2b. Elastic scattering cross sections for electrons in Br.

e + Br → e + Br

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0.0680	44.0	5.44	21.5
0.136	22.9	6.80	24.5
0.680	1.94	8.16	26.7
1.50	5.04	9.52	28.1
2.04	8.23	10.9	28.7
2.86	12.5	12.2	28.6
3.40	14.9		
4.08	17.5		

Cont. Next Column



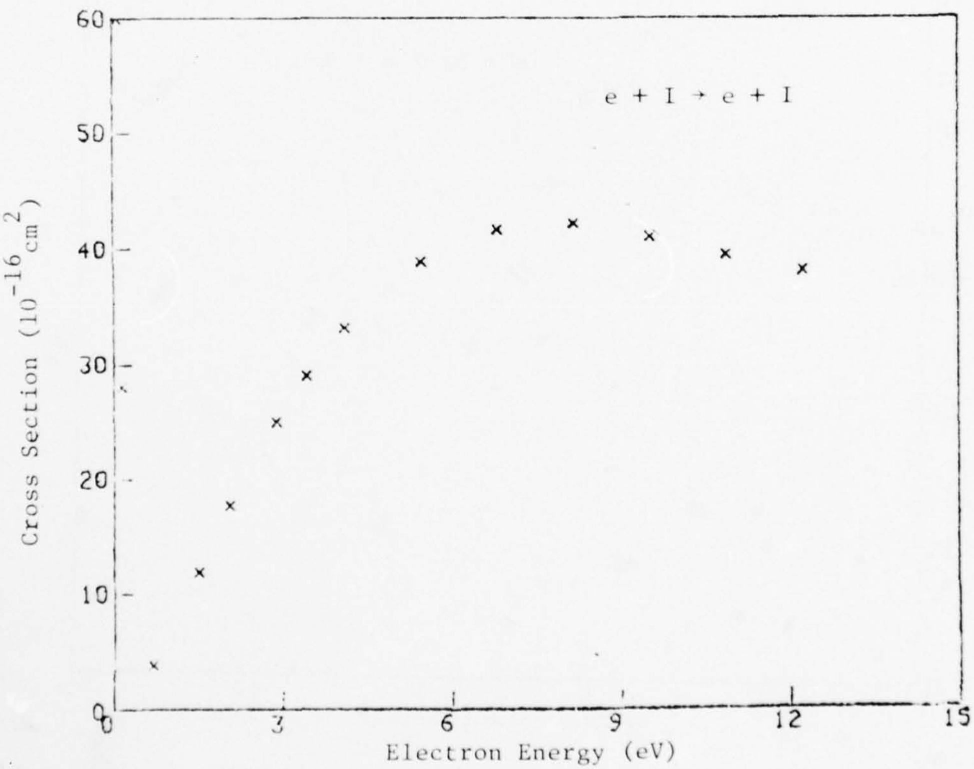
Reference: E. J. Robinson and S. Geltman, Phys. Rev. 153, 4 (1967)

Tabular and Graphical Data C-1.2c. Elastic scattering cross sections for electrons in I.

$$e + I \rightarrow e + I$$

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
0.0680	60.0	5.44	38.9
0.136	28.0	6.80	41.8
0.680	3.87	8.16	42.3
1.50	11.8	9.52	41.1
2.04	17.7	10.9	39.5
2.86	25.0	12.2	38.0
3.40	29.0		
4.08	33.1		

Cont. Next Column

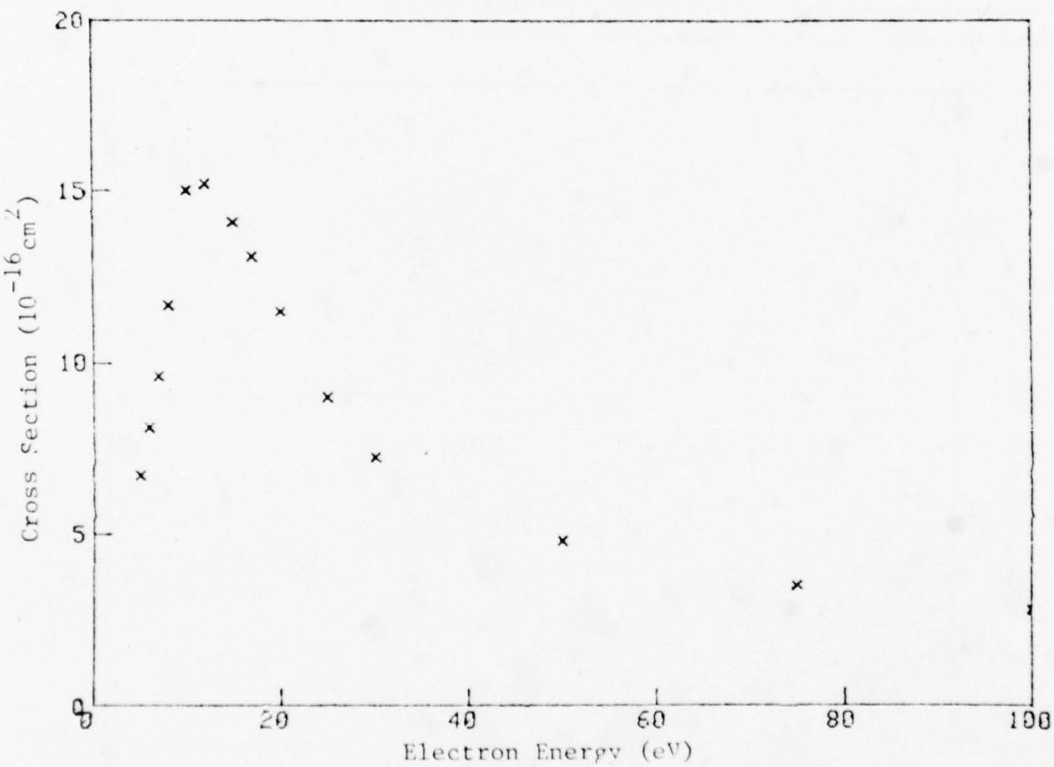


Reference: E. J. Robinson and S. Geltman, Phys. Rev. 153, 4 (1967)

Tabular and Graphical Data C-1.3. Momentum transfer cross section for electrons in Ar.

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
5	6.7	17	13.1
6	8.1	20	11.5
7	9.6	25	9.0
8	11.7	30	7.2
10	15.0	50	4.8
12	15.2	75	3.5
15	14.1	100	2.8

Cont. Next Column



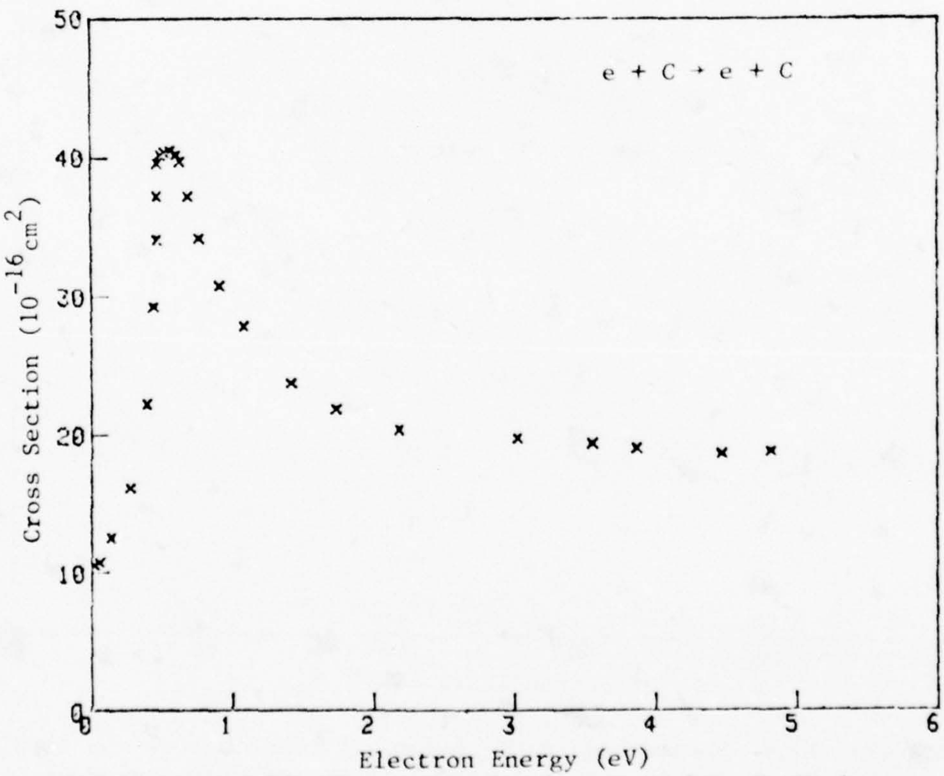
Reference: F. E. Spencer and A. V. Phelps, Proceedings of the 15th Symposium on the Engineering Aspects of Magnetohydrodynamics, Philadelphia, Pa., May, 1976. Paper IX.9.1

Tabular and Graphical Data C-1.4. Elastic scattering cross sections for electrons in C.

$$e + C \rightarrow e + C$$

Electron Energy (eV)	Cross Section ($10^{-16} cm^2$)	Electron Energy (eV)	Cross Section ($10^{-16} cm^2$)	Electron Energy (eV)	Cross Section ($10^{-16} cm^2$)
0.0152	10.5	0.490	40.2	1.41	23.7
0.0516	10.7	0.522	40.4	1.73	21.8
0.134	12.5	0.559	40.6	2.18	20.3
0.271	16.2	0.602	40.3	3.02	19.7
0.389	22.3	0.628	39.7	3.56	19.4
0.440	29.3	0.681	37.2	3.88	19.0
0.466	34.1	0.764	34.2	4.48	18.6
0.465	37.2	0.907	30.8	4.82	18.8
0.472	39.6	1.08	27.9		

Cont. Next Column   Cont. Next Column

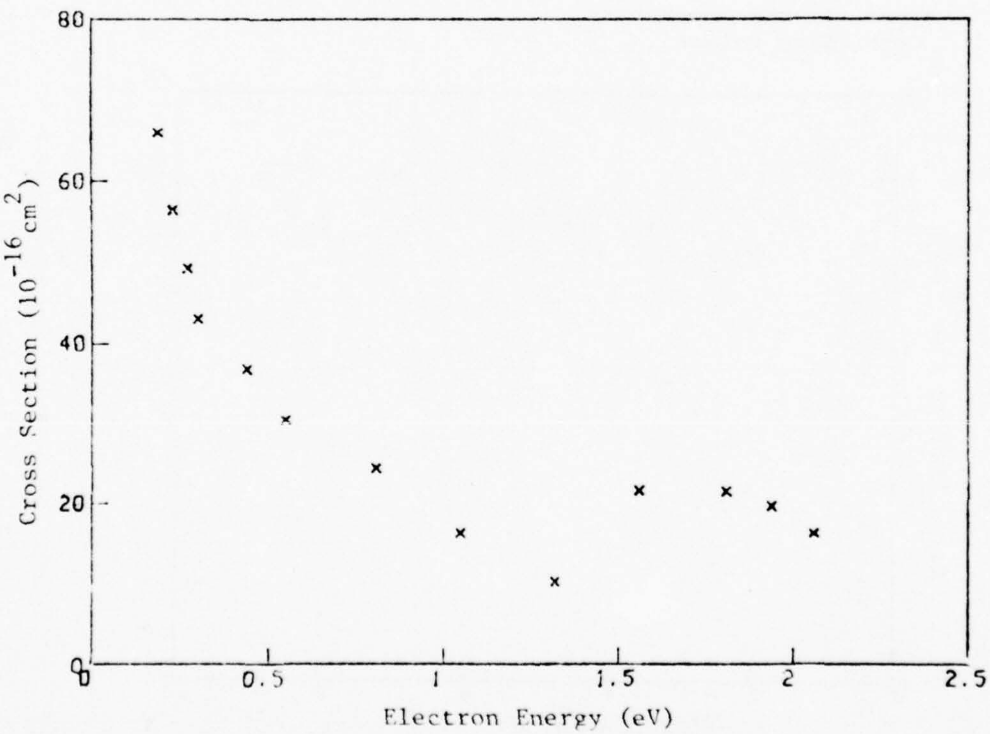


Reference: L. D. Thomas, R. S. Oberoi, and R. K. Nesbet, Phys. Rev. A 10, 1605 (1974)

Tabular and Graphical Data C-1.5. Total scattering cross sections for electrons in N.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0.190	66.0	1.05	16.1
0.230	56.5	1.32	10.1
0.270	49.3	1.56	21.5
0.300	43.0	1.81	21.4
0.440	36.7	1.94	19.6
0.550	30.4	2.06	16.2
0.810	24.3		

Cont. Next Column

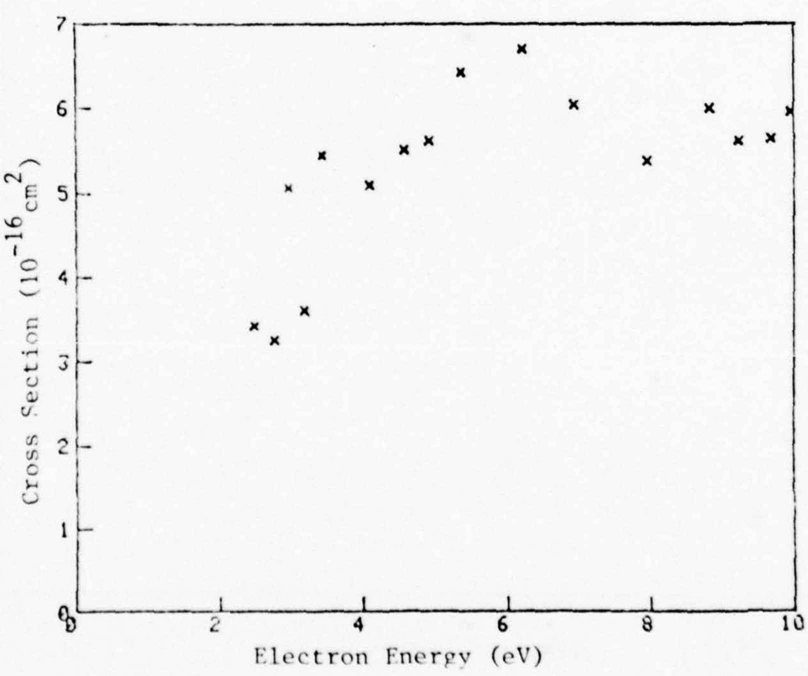


Reference: T. M. Miller, P. N. Eisner and B. Bederson, Bull. Am. Phys. Soc. 15, 416 (1970)

Tabular and Graphical Data C-1.6. Total scattering cross sections for electrons in N.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
2.47	3.43	6.94	6.05
2.75	3.26	7.34	7.24
2.95	5.07	7.95	5.38
3.18	3.61	8.42	7.08
3.41	5.45	8.83	6.00
4.09	5.10	9.23	5.62
4.56	5.51	9.68	5.65
4.90	5.62	9.96	5.96
5.36	6.42		
6.21	6.71		

Cont. Next Column



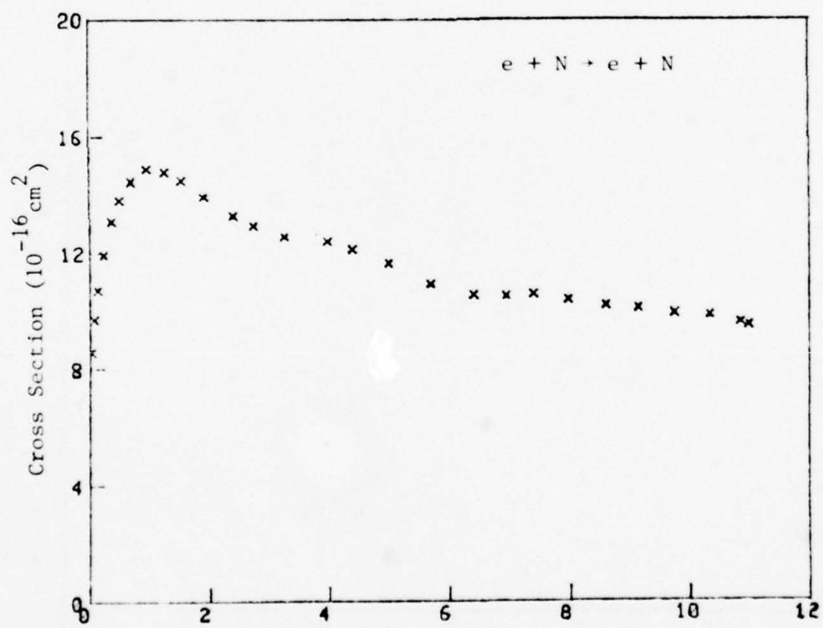
Reference: R. H. Neynaber, L. L. Marino, E. W. Rothe, S. M. Trujillo, Phys. Rev. 129, 2069 (1963)

Tabular and Graphical Data C-1.7. Elastic scattering cross sections for electrons in N.

$e + N \rightarrow e + N$

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0.0142	8.58	1.89	13.9	7.39	10.6
0.0620	9.69	2.38	13.3	7.97	10.4
0.118	10.7	2.73	12.9	8.61	10.2
0.223	11.9	3.24	12.6	9.15	10.1
0.353	13.1	3.97	12.4	9.75	9.90
0.494	13.8	4.38	12.1	10.3	9.82
0.684	14.5	4.98	11.7	10.9	9.58
0.951	14.9	5.69	10.9	11.0	9.48
1.25	14.8	6.39	10.6		
1.53	14.5	6.94	10.5		

Cont. Next Column　　Cont. Next Column



Reference: L. D. Thomas, R. S. Oberoi, and R. K. Nesbet, Phys. Rev. A 10, 1605 (1974)

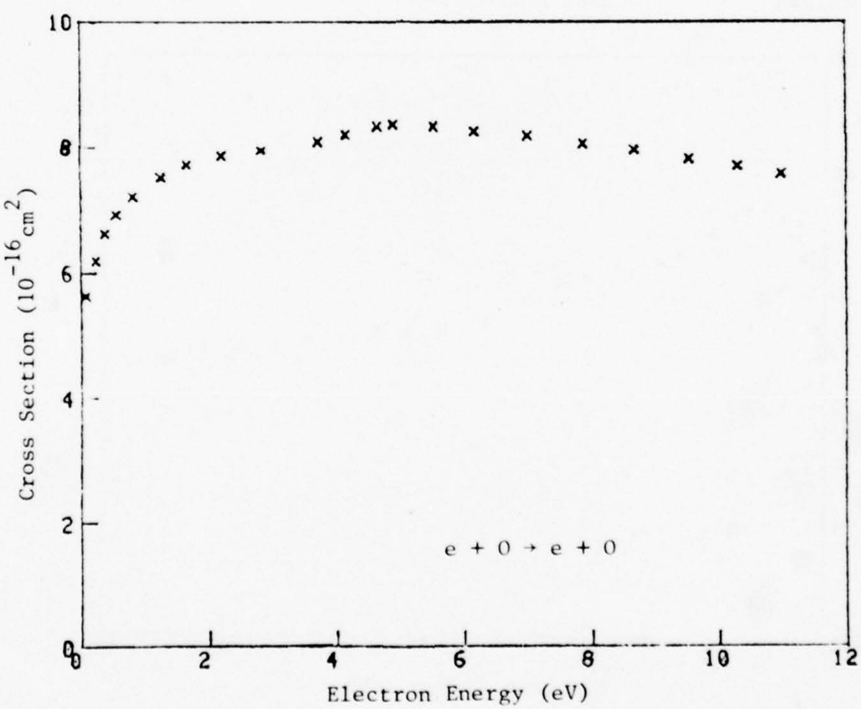
Tabular and Graphical Data C-1.8. Elastic scattering cross sections for electrons in O.

$e + O \rightarrow e + O$

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
0.0684	5.63	2.81	7.95	7.87	8.05
0.221	6.20	3.71	8.07	8.67	7.96
0.376	6.62	4.14	8.18	9.52	7.82
0.544	6.93	4.64	8.32	10.3	7.70
0.800	7.22	4.88	8.36	11.0	7.57
1.25	7.52	5.53	8.32		
1.65	7.72	6.16	8.24		
2.20	7.86	7.01	8.17		

Cont. Next Column

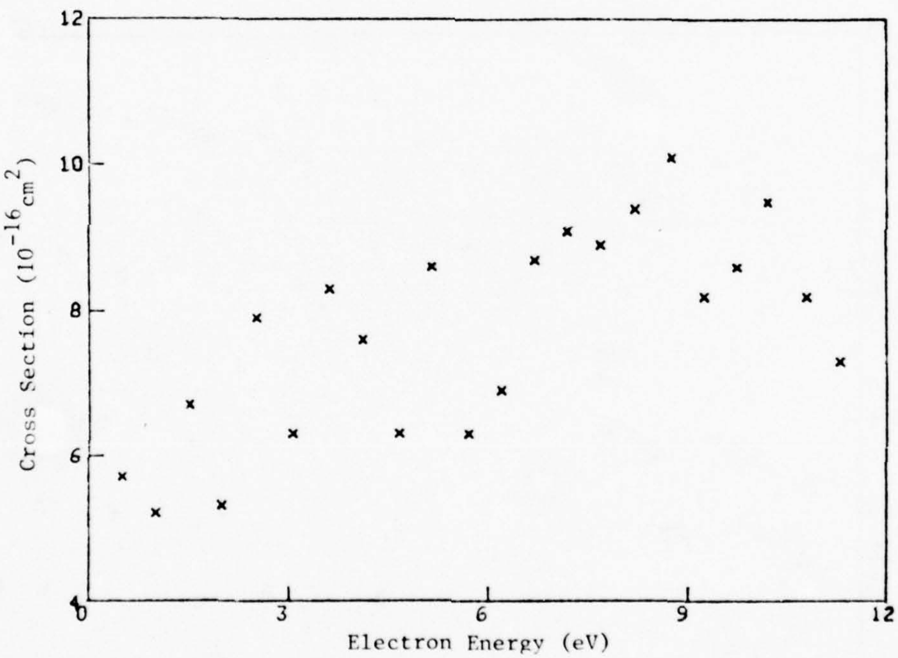
Cont. Next Column



Reference: L. D. Thomas, R. S. Oberoi and R. K. Nesbet, Phys. Rev. A 10, 1605 (1974)

Tabular and Graphical Data C-1.9a. Total scattering cross sections for electrons in O.

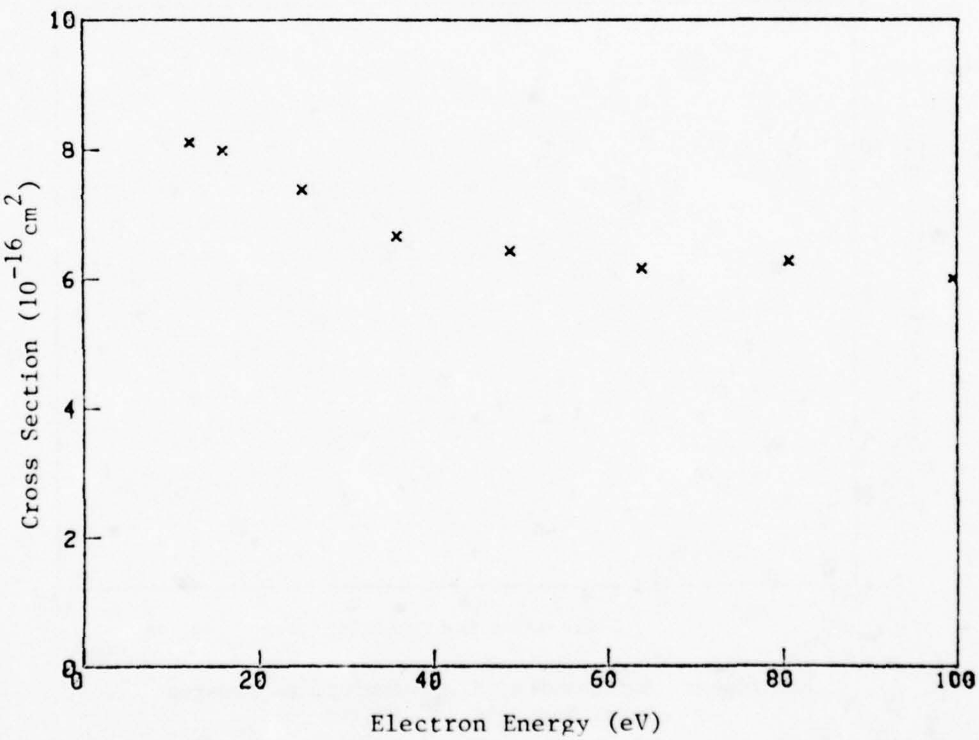
Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
11.3	7.30	7.20	9.10	3.05	6.30
10.8	8.20	6.70	8.70	2.50	7.90
10.2	9.50	6.20	6.90	2.00	5.30
9.75	8.60	5.70	6.30	1.50	6.70
9.25	8.20	5.15	8.60	1.000	5.20
8.75	10.1	4.65	6.30	0.500	5.70
8.20	9.40	4.10	7.60		
7.70	8.90	3.60	8.30		
Cont. Next Column		Cont. Next Column			



Reference: G. Sunshine, B. B. Aubrey, B. Bederson, Phys. Rev. 154, 1 (1967)

Tabular and Graphical Data C-1.9b. Total scattering cross sections for electrons in O.

Electron Energy eV	Cross Section $10^{-16}cm^2$
12.1	8.11
15.8	7.99
24.9	7.38
35.7	6.66
48.8	6.43
63.8	6.16
80.7	6.27
99.6	6.01

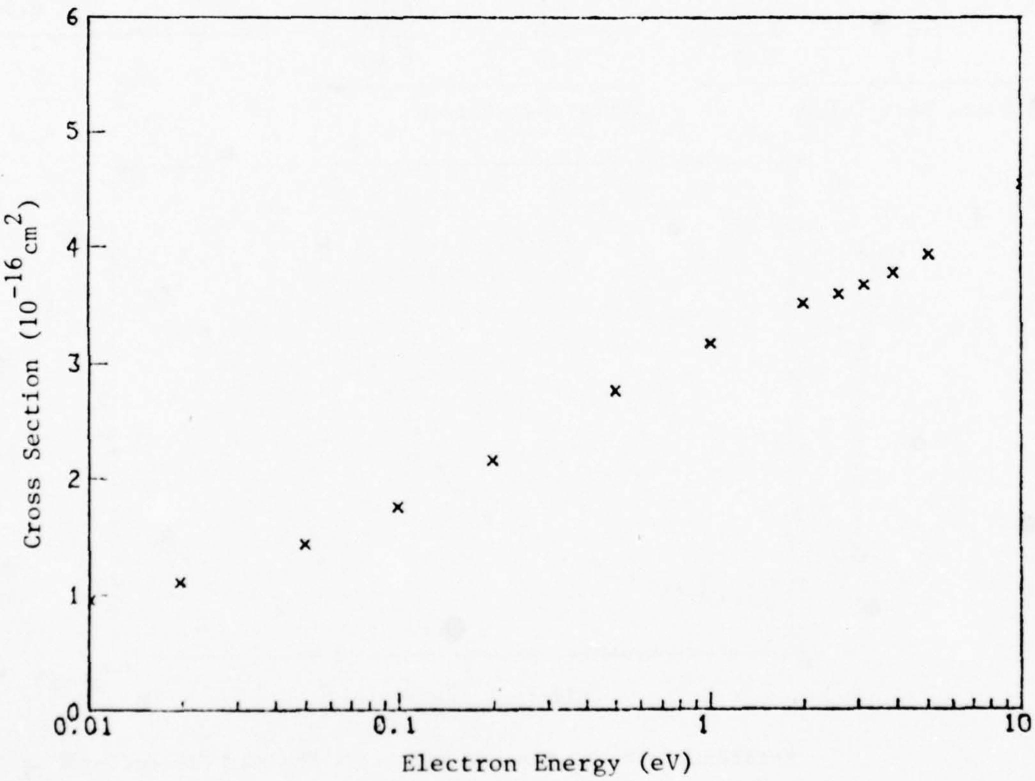


Reference: G. Sunshine, B. B. Aubrey, and B. Bederson, Phys. Rev. 154, 1 (1967)

Tabular and Graphical Data C-1.10a. Momentum transfer cross sections for electrons in O.

Electron Energy (eV)	Cross Section ($10^{-16} cm^2$)	Electron Energy (eV)	Cross Section ($10^{-16} cm^2$)
0.010	0.95	2.0	3.5
0.020	1.1	2.6	3.6
0.049	1.4	3.1	3.7
0.098	1.8	3.9	3.8
0.20	2.2	5.1	3.9
0.50	2.8	10	4.5
1.0	3.2		

Cont. Next Column

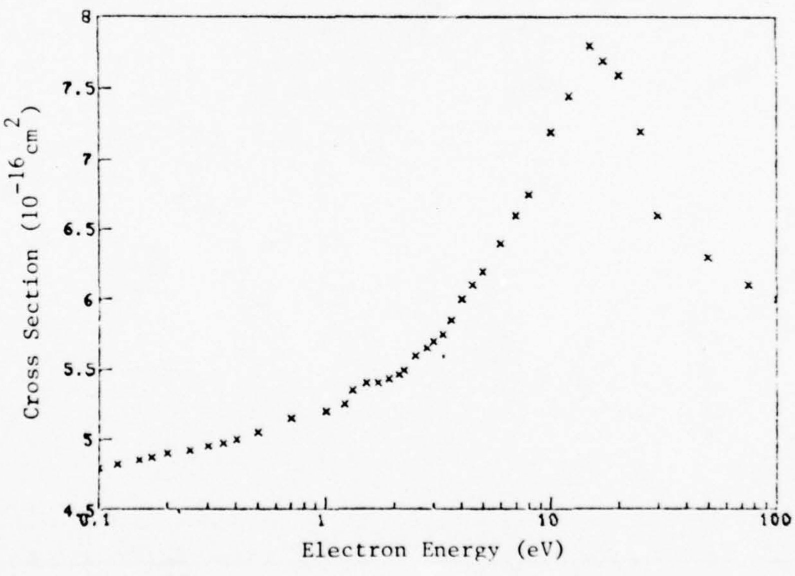


Reference: Y. Itikawa, At. Dat. and Nuc. Dat. Tables 21, 69 (1978)

Tabular and Graphical Data C-1.10b. Momentum transfer cross sections for electrons in O.

Electron Energy eV	Cross Section 10^{-14} cm^2	Electron Energy eV	Cross Section 10^{-14} cm^2	Electron Energy eV	Cross Section 10^{-14} cm^2
0.10	4.80	1.5	5.40	7.0	6.60
0.12	4.82	1.7	5.40	8.0	6.75
0.15	4.85	1.9	5.43	10.0	7.20
0.17	4.87	2.1	5.46	12	7.45
0.20	4.90	2.2	5.49	15	7.80
0.25	4.92	2.5	5.60	17	7.70
0.30	4.95	2.8	5.65	20	7.60
0.35	4.97	3.0	5.70	25	7.20
0.40	5.00	3.3	5.75	30	6.60
0.50	5.05	3.6	5.85	50	6.30
0.70	5.15	4.0	6.00	75	6.10
1.0	5.20	4.5	6.10	100	6.00
1.2	5.25	5.0	6.20		
1.3	5.35	6.0	6.40		

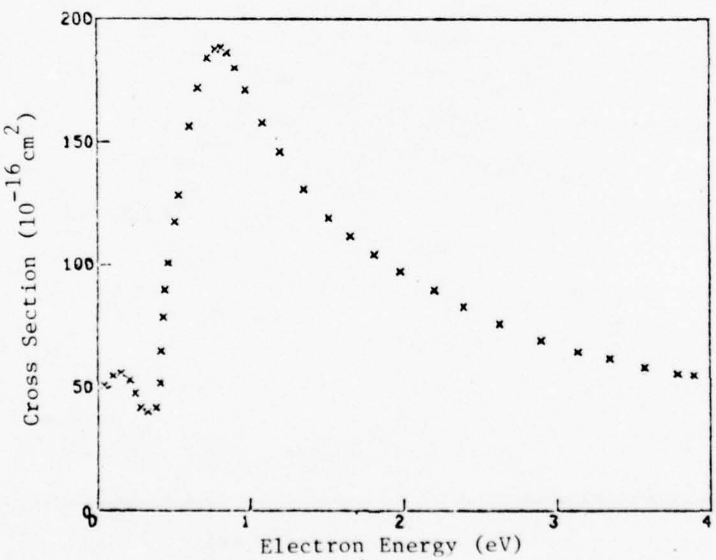
Cont. Next Column   Cont. Next Column



Reference: F. E. Spencer and A. V. Phelps, Proceedings of the 15th Symposium on the Engineering Aspects of Magnetohydrohynamics, Philadelphia, Pa., May, 1976. Paper IX.9.1

Tabular and Graphical Data C-1.11. Total scattering cross sections for electrons in Hg.

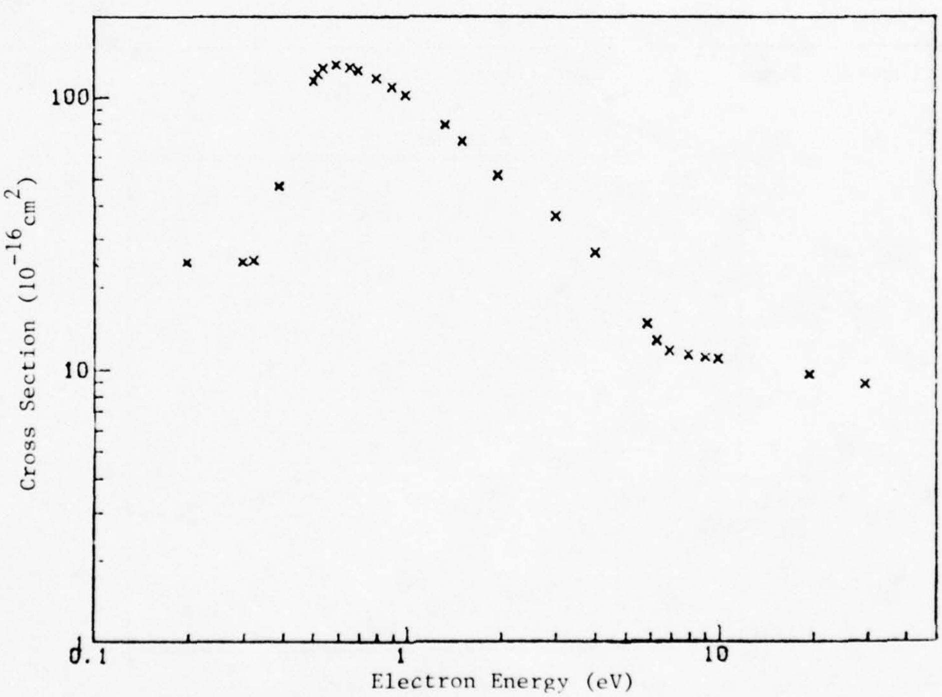
Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0.038	50	0.50	120	1.5	120
0.098	54	0.53	130	1.7	110
0.15	55	0.60	150	1.8	100
0.21	52	0.65	170	2.0	96
0.24	47	0.72	180	2.2	89
0.28	41	0.77	190	2.4	82
0.32	40	0.81	190	2.6	75
0.37	41	0.85	180	2.9	68
0.40	51	0.90	180	3.1	64
0.41	64	0.97	170	3.4	61
0.42	78	1.1	160	3.6	58
0.43	89	1.2	140	3.8	55
0.46	100	1.4	130	3.9	54
Cont. Next Column		Cont. Next Column			



Reference: P. K. Hutt, J. Phys. B 8, L88 (1975)

Tabular and Graphical Data C-1.12. Momentum transfer cross sections for electrons in Hg.

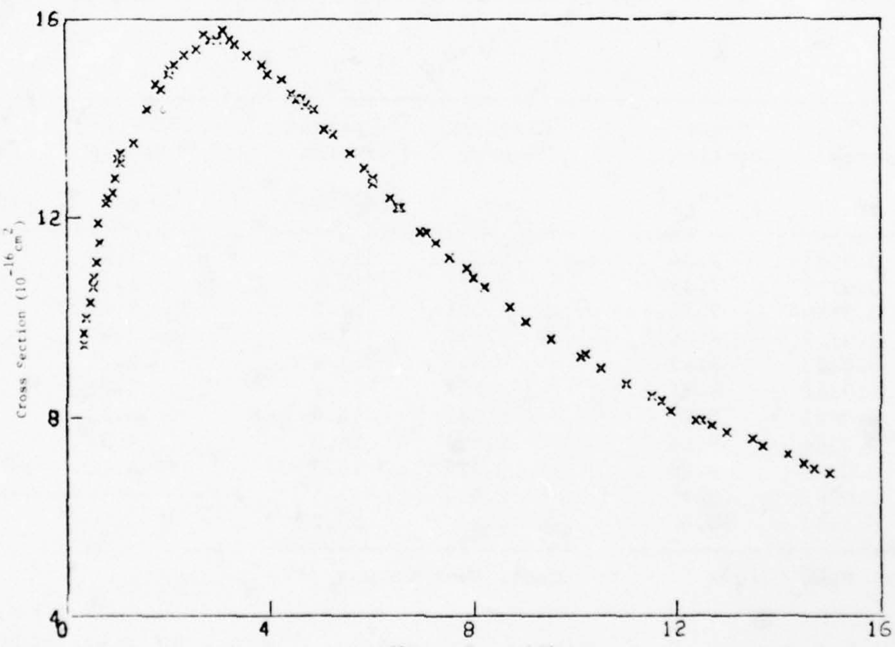
Electron Energy (eV)	Cross Section ($10^{-16}cm^2$)	Electron Energy (eV)	Cross Section ($10^{-16}cm^2$)	Electron Energy (eV)	Cross Section ($10^{-16}cm^2$)
0.099	24.7	0.65	130	4.0	26.9
0.20	24.8	0.70	126	5.9	14.7
0.30	24.8	0.79	118	6.3	12.7
0.32	25.1	0.89	110	6.9	11.7
0.39	47.1	0.99	103	8.0	11.3
0.50	115	1.3	79.2	9.0	11.1
0.52	123	1.5	69.0	10.0	10.9
0.54	129	2.0	51.7	20	9.58
0.59	133	3.0	36.4	30	8.85
Cont. Next Column		Cont. Next Column			



Reference: S. D. Rockwood, Phys. Rev. A 8, 2348 (1973)

Tabular and Graphical Data C-1.13. Total scattering cross sections for electrons in H_2.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0.324	9.45	2.85	15.6	7.54	11.2
0.324	9.69	2.99	15.6	7.88	11.0
0.384	9.99	3.09	15.8	8.00	10.8
0.443	10.3	3.23	15.6	8.24	10.6
0.503	10.6	3.33	15.5	8.72	10.2
0.523	10.8	3.57	15.3	9.03	9.91
0.582	11.1	3.88	15.1	9.53	9.57
0.642	11.5	3.98	14.9	10.1	9.21
0.622	11.9	4.26	14.8	10.2	9.27
0.761	12.3	4.46	14.5	10.5	8.98
0.801	12.4	4.56	14.4	11.0	8.66
0.901	12.5	4.66	14.4	11.5	8.42
0.960	12.8	4.74	14.3	11.7	8.32
1.06	13.1	4.90	14.2	11.9	8.11
1.000	13.2	5.10	13.8	12.4	7.93
1.06	13.3	5.28	13.7	12.5	7.93
1.32	13.5	5.61	13.3	12.7	7.83
1.58	14.2	5.89	13.0	13.0	7.69
1.76	14.7	6.05	12.8	13.5	7.55
1.86	14.6	6.05	12.7	13.7	7.41
2.01	14.9	6.39	12.4	14.2	7.24
2.03	15.0	6.53	12.2	14.5	7.06
2.13	15.1	6.59	12.2	14.7	6.96
2.33	15.3	6.99	11.7	15.0	6.86
2.57	15.4	7.09	11.7		
2.73	15.7	7.28	11.5		
Cont. Next Column		Cont. Next Column			



Reference: D. E. Golden, H. W. Bandel and J. A. Salerno, Phys. Rev. 146 40 (1966).

Tabular Data C-1.14a. Momentum transfer cross sections for electrons in H_2.

$$e + H_2 \rightarrow e + H_2$$

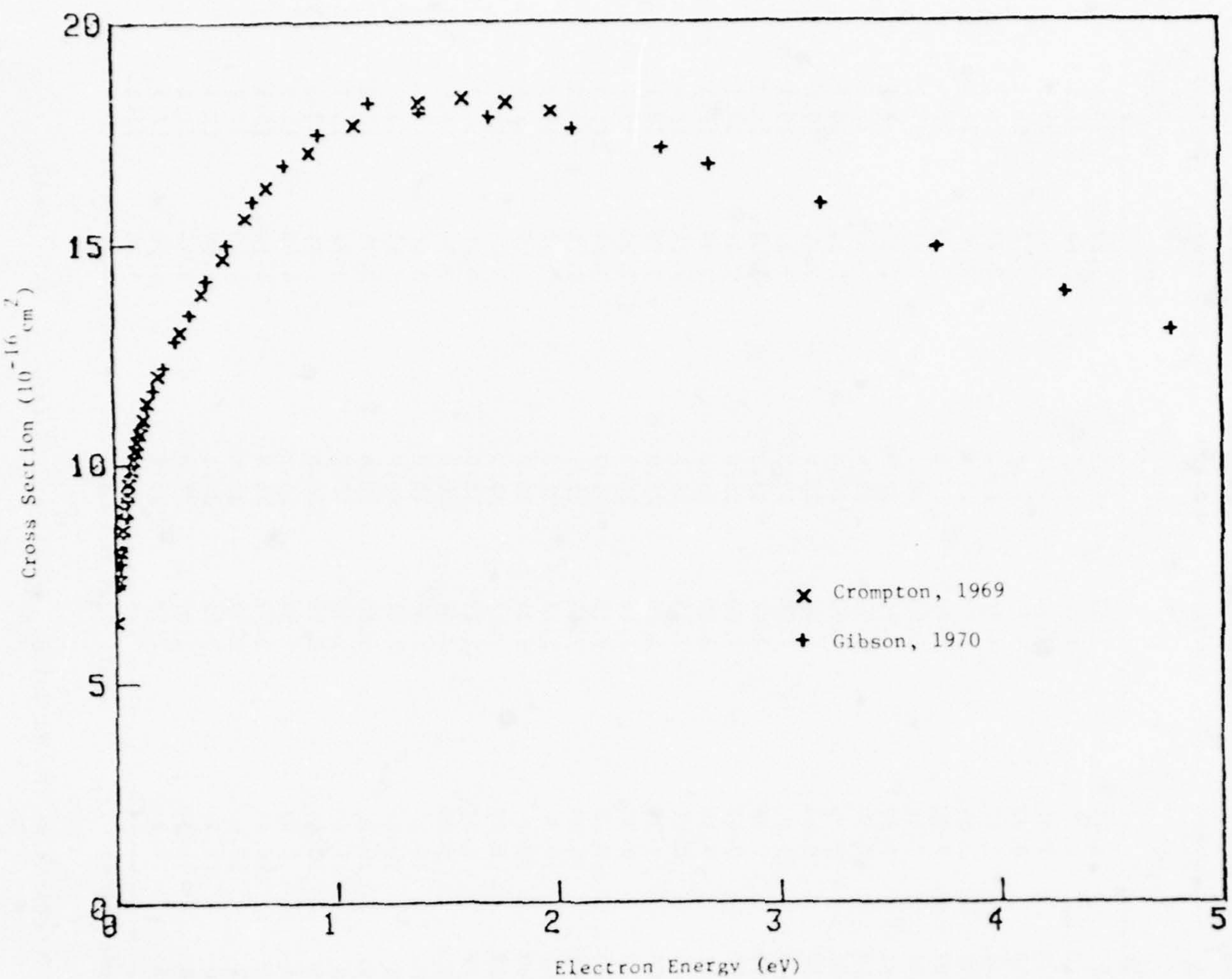
Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
0	6.40	0.090	10.3	0.60	15.6
0.010	7.30	0.10	10.5	0.70	16.3
0.020	8.00	0.11	10.7	0.90	17.1
0.030	8.50	0.13	11.0	1.1	17.7
0.040	8.96	0.15	11.4	1.4	18.2
0.050	9.28	0.20	12.0	1.6	18.3
0.060	9.56	0.30	13.0	1.8	18.2
0.070	9.85	0.40	13.9	2.0	18.0
0.080	10.1	0.50	14.7		
Cont. Next Column		Cont. Next Column			

Reference: R. W. Crompton, D. K. Gibson, and A. I. McIntosh, Australian J. Phys. 22, 715 (1969)

Tabular Data C-1.14b. Momentum transfer cross sections for electrons in H_2.

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
0.0101	7.26	0.143	11.3	1.40	18.0
0.0131	7.45	0.175	11.7	1.72	17.9
0.0169	7.76	0.221	12.2	2.09	17.6
0.0218	8.04	0.272	12.8	2.49	17.2
0.0283	8.43	0.340	13.4	2.70	16.8
0.0361	8.81	0.417	14.2	3.21	15.9
0.0462	9.25	0.512	15.0	3.73	14.9
0.0586	9.64	0.634	16.0	4.31	13.9
0.0748	9.98	0.778	16.8	4.78	13.0
0.0942	10.4	0.933	17.5		
0.115	10.8	1.17	18.2		
Cont. Next Column		Cont. Next Column			

Reference: D. K. Gibson, Australian J. Phys. 23, 683 (1970)

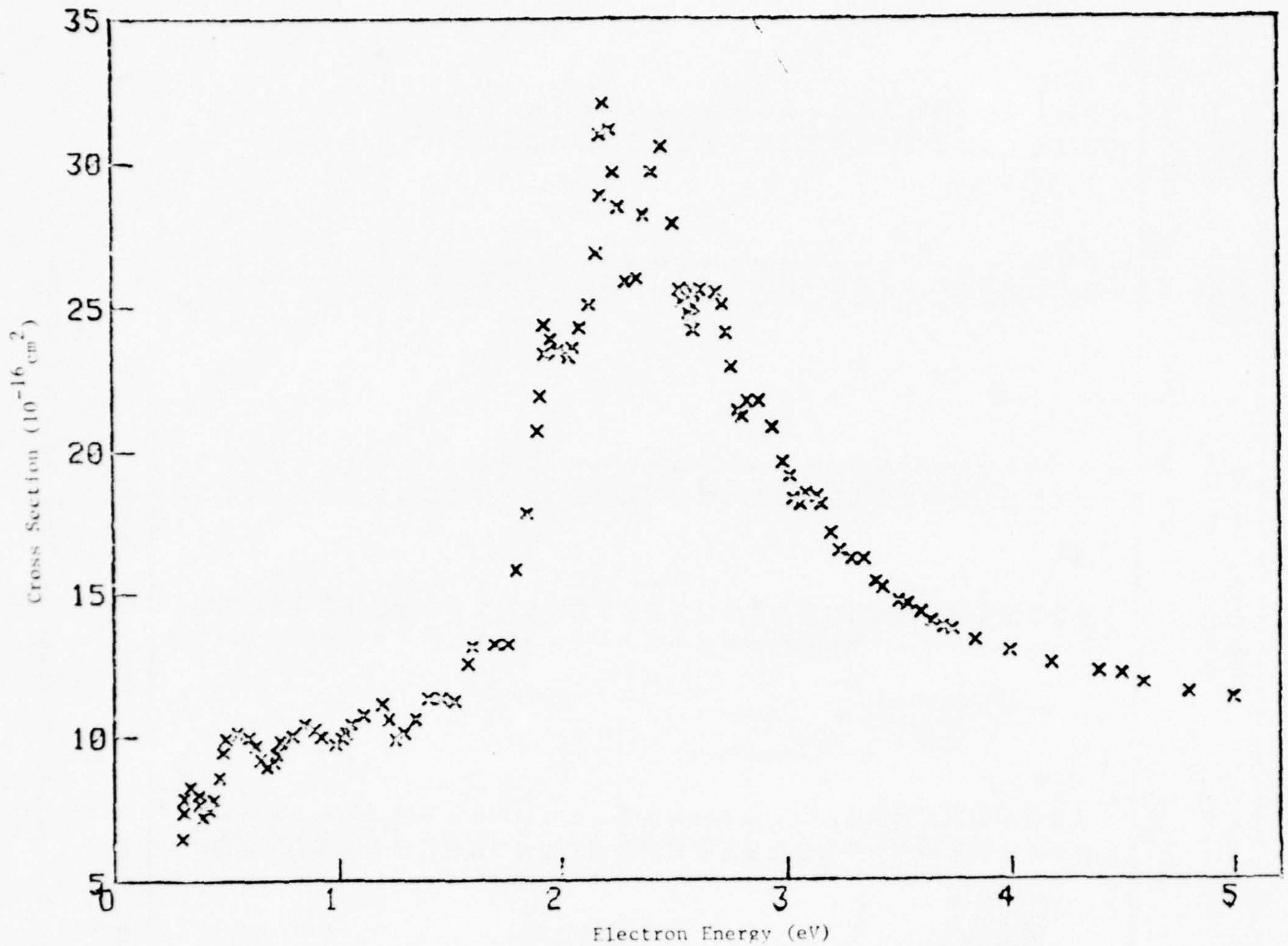


Graphical Data C-1.14c. Momentum transfer cross sections for electrons in H_2.

Tabular Data C-1.15a. Total scattering cross sections for electrons in N_2.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0.303	6.44	1.57	11.9	2.62	25.6
0.310	7.35	1.58	12.5	2.64	26.1
0.309	7.85	1.60	13.1	2.69	25.5
0.338	8.22	1.70	13.2	2.72	25.1
0.375	7.96	1.76	13.2	2.74	24.1
0.382	7.64	1.80	15.8	2.76	22.9
0.397	7.20	1.85	17.8	2.79	21.4
0.426	7.42	1.90	20.7	2.81	21.2
0.441	7.82	1.91	21.9	2.83	21.7
0.469	8.55	1.93	23.4	2.88	21.7
0.483	9.45	1.93	24.4	2.94	20.8
0.497	9.89	1.96	23.9	2.99	19.6
0.548	10.1	1.99	23.5	3.02	19.1
0.599	9.96	2.04	23.3	3.04	18.3
0.628	9.67	2.06	23.6	3.07	18.1
0.651	9.16	2.09	24.3	3.09	18.5
0.680	8.91	2.13	25.1	3.14	18.4
0.709	9.09	2.16	26.9	3.16	18.1
0.723	9.38	2.18	28.9	3.20	17.1
0.737	9.78	2.18	31.0	3.24	16.5
0.795	10.00	2.19	32.1	3.29	16.2
0.846	10.4	2.22	31.2	3.35	16.2
0.890	10.2	2.24	29.7	3.40	15.4
0.919	9.93	2.26	28.5	3.43	15.2
0.978	9.71	2.29	25.9	3.50	14.7
1.01	9.89	2.34	26.0	3.54	14.6
1.03	10.1	2.37	28.2	3.60	14.3
1.05	10.4	2.41	29.7	3.65	14.0
1.11	10.7	2.45	30.6	3.70	13.8
1.19	11.1	2.50	27.9	3.74	13.7
1.22	10.6	2.53	25.6	3.84	13.3
1.25	9.85	2.54	25.2	4.00	12.9
1.29	10.1	2.57	24.8	4.19	12.5
1.34	10.6	2.58	24.6	4.40	12.2
1.40	11.3	2.59	24.2	4.50	12.1
1.46	11.3	2.59	25.0	4.60	11.8
1.52	11.2	2.59	25.5	4.80	11.5
				5.00	11.3
Cont. Next Column		Cont. Next Column			

Reference: D. E. Golden, Phys. Rev. Letters 17, 847 (1966)



Graphical Data C-1.15a. Total scattering cross sections for electrons in N_2.

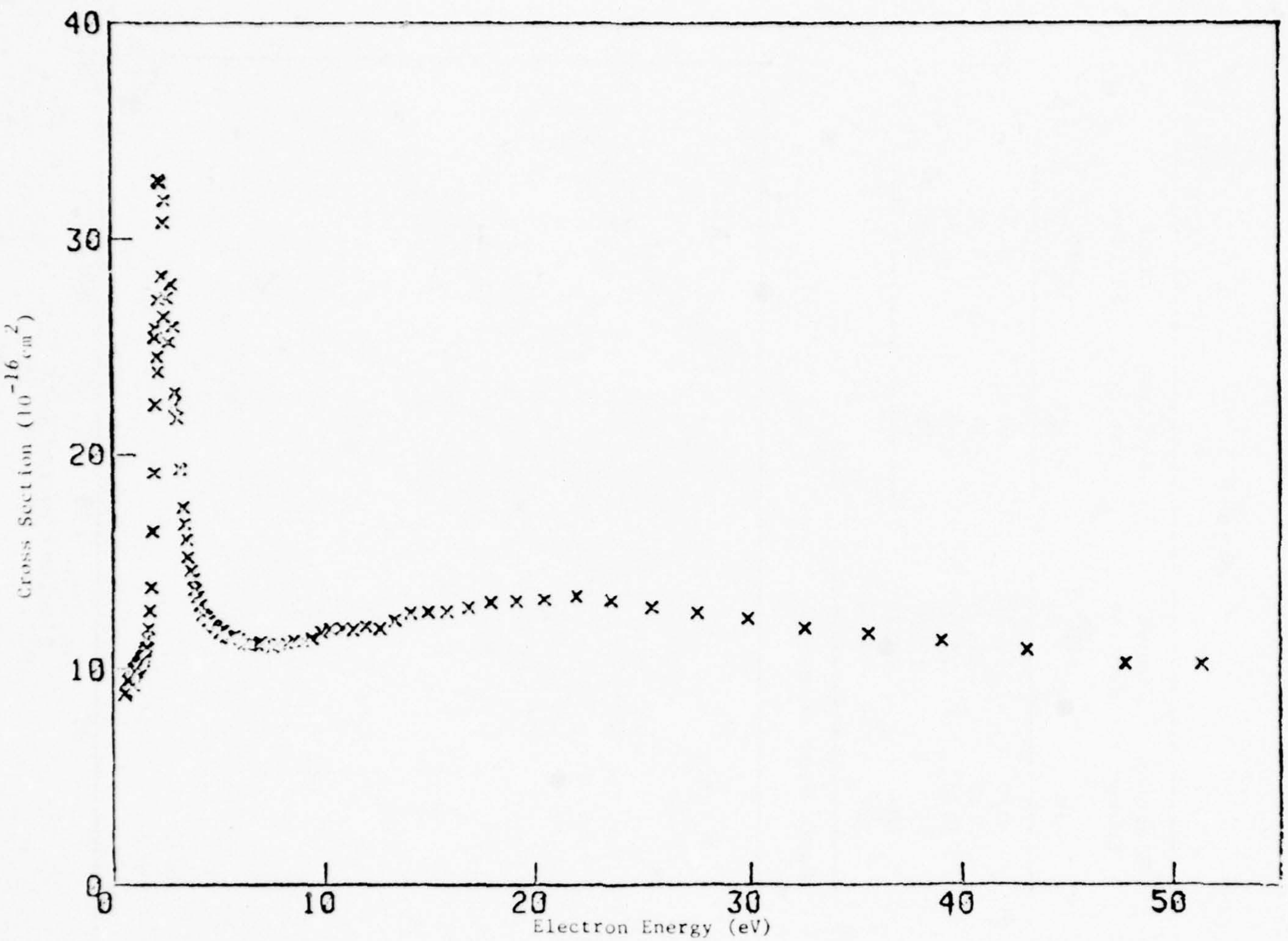
Tabular Data C-1.15b. Total scattering cross sections for electrons in N_2.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0.519	8.79	2.40	30.8	8.10	11.2
0.570	8.94	2.46	31.8	8.46	11.3
0.628	9.43	2.53	27.3	8.85	11.3
0.695	9.38	2.59	25.2	9.27	11.4
0.774	9.53	2.66	27.9	9.72	11.7
0.868	9.73	2.73	25.9	10.2	11.8
0.916	9.18	2.80	22.2	10.7	11.9
0.943	9.85	2.87	22.8	11.3	11.8
0.972	9.96	2.95	21.6	11.9	12.0
1.00	9.91	3.03	19.3	12.5	11.9
1.02	9.86	3.12	19.2	13.2	12.2
1.06	10.0	3.21	17.5	14.0	12.5
1.09	10.1	3.30	16.7	14.9	12.6
1.13	10.1	3.39	16.0	15.8	12.6
1.16	10.2	3.49	15.2	16.8	12.8
1.20	10.1	3.59	14.6	17.9	13.1
1.24	10.3	3.70	14.1	19.1	13.1
1.29	10.4	3.81	13.6	20.4	13.2
1.33	10.4	3.93	13.3	21.9	13.4
1.38	10.6	4.05	12.9	23.6	13.2
1.43	10.8	4.18	12.5	25.4	12.9
1.49	11.0	4.31	12.3	27.5	12.6
1.54	11.4	4.45	12.2	29.9	12.3
1.60	11.9	4.60	12.0	32.6	11.9
1.67	12.7	4.75	11.9	35.6	11.7
1.74	13.8	4.92	11.6	39.1	11.4
1.81	16.4	5.09	11.7	43.1	10.9
1.87	19.1	5.27	11.4	47.8	10.3
1.91	22.3	5.46	11.4	51.3	10.3
1.95	25.4	5.66	11.5		
1.99	25.8	5.87	11.4		
2.04	24.5	6.09	11.1		
2.09	23.8	6.33	11.1		
2.13	27.2	6.58	11.1		
2.18	32.8	6.85	11.2		
2.24	32.6	7.13	11.1		
2.29	28.3	7.43	11.0		
2.35	26.4	7.75	11.1		

Cont. Next Column

Cont. Next Column

Reference: R. Kennerly, Phys. Rev. A (submitted)



Graphical Data C-1.15b. Total scattering cross sections for electrons in N_2.

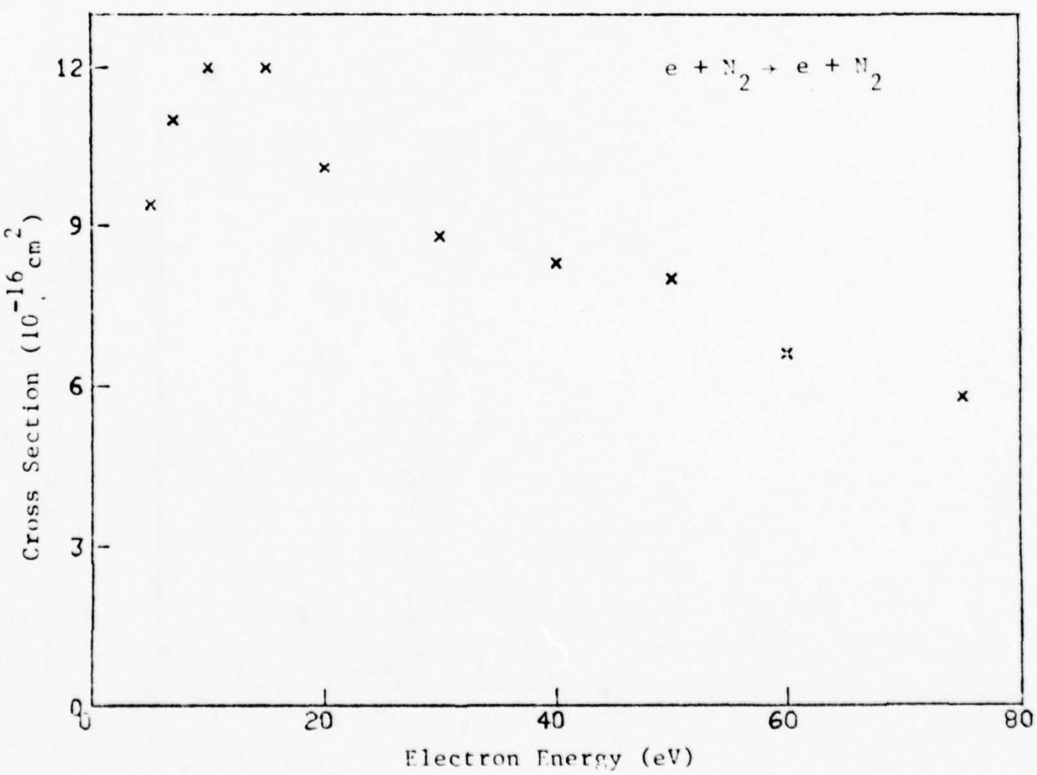
Tabular and Graphical Data C-1.16a. Elastic scattering cross sections for electrons in N_2.

$$e + N_2 \rightarrow e + N_2$$

Electron Energy (eV)	Cross Section ($10^{-16}cm^2$)
5.0	9.40
7.0	11.0
10.0	12.0
15	12.0
20	10.1
30	8.80

Cont. Next Column

Electron Energy (eV)	Cross Section ($10^{-16}cm^2$)
40	8.30
50	8.00
60	6.60
75	5.80

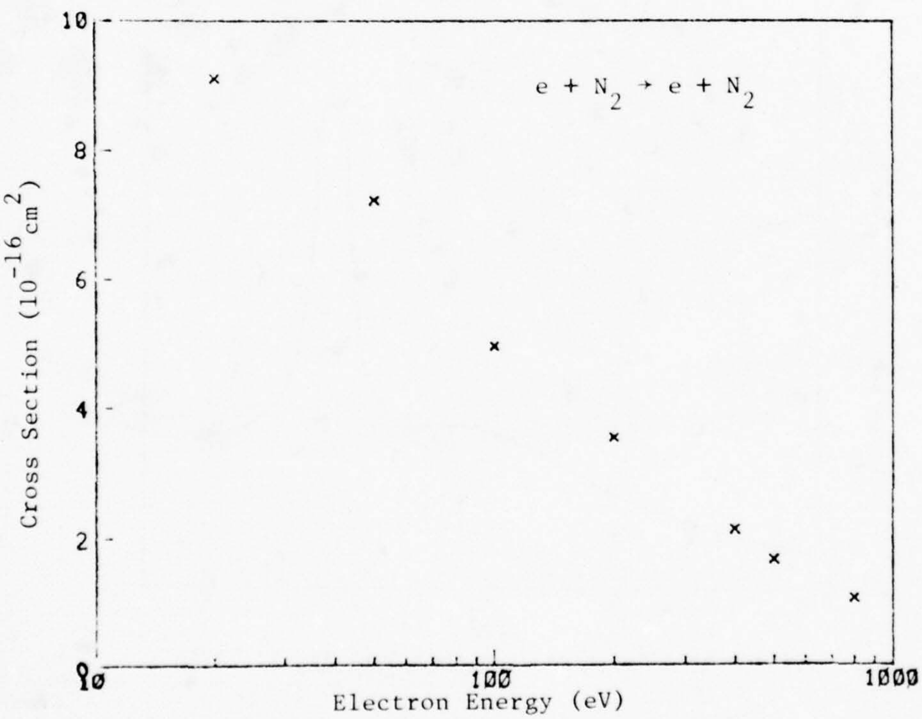


Reference: S. K. Srivastava, A. Chutjian and S. Trajmar, J. Chem. Phys. 64, 1340 (1976)

Tabular and Graphical Data C-1.16b. Elastic scattering cross sections for electrons in N_2.

$$e + N_2 \rightarrow e + N_2$$

Electron Energy eV	Cross Section $10^{-16} cm^2$
20	9.13
50	7.22
100	4.96
200	3.53
400	2.11
500	1.65
800	1.06

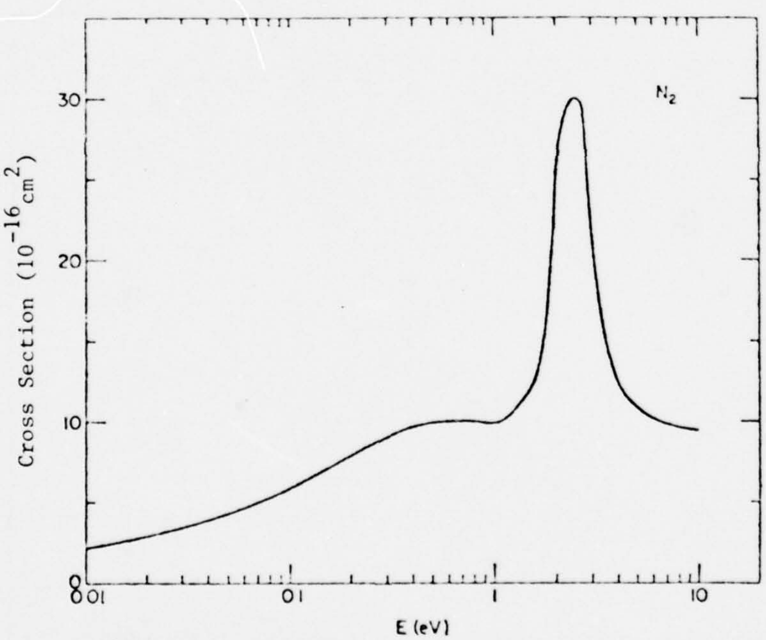


Reference: R. D. DuBois and M. E. Rudd, J. Phys. B 9, 2657 (1976)

Tabular and Graphical Data C-1.17a. Momentum transfer cross sections for electrons in N_2.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0.010	2.24	1.7	15.4	2.9	24.0
0.020	2.98	1.8	17.7	3.0	22.0
0.050	4.39	1.9	20.7	3.1	19.0
0.10	5.90	2.0	23.5	3.3	16.4
0.20	7.92	2.0	25.9	3.7	14.0
0.50	10.0	2.1	28.2	4.2	11.9
0.84	10.1	2.3	29.6	5.1	10.9
1.0	10.0	2.5	30.0	6.6	10.1
1.3	10.9	2.7	29.6	10.0	9.53
1.5	11.9	2.8	28.4		
1.6	13.3	2.8	25.9		

Cont. Next Column   Cont. Next Column

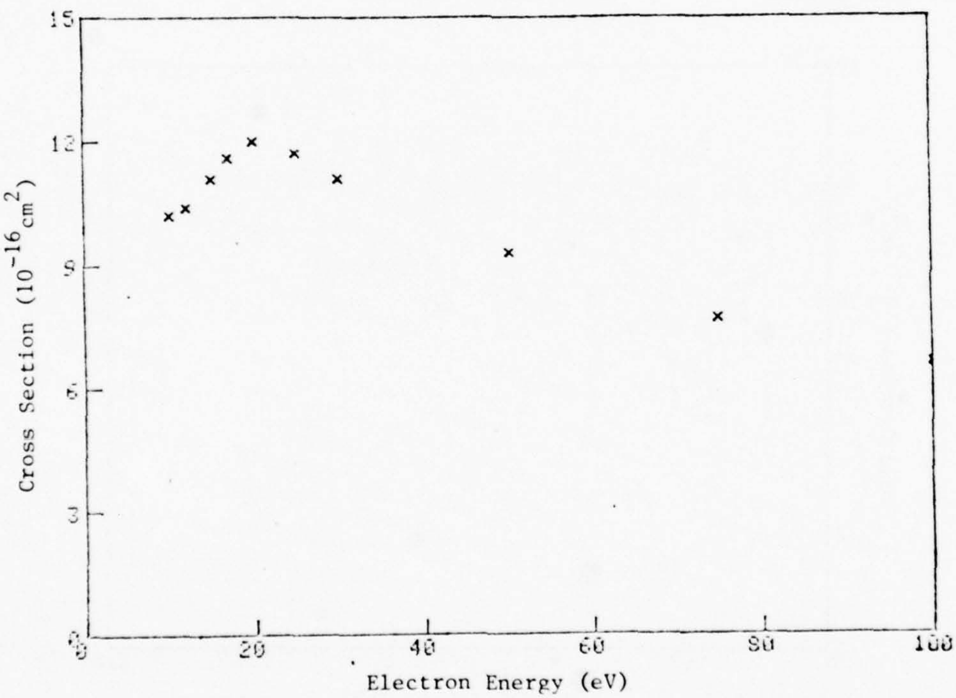


Reference: Y. Itikawa, Atomic Data 14, 1 (1974)

Tabular and Graphical Data C-1.17b. Momentum transfer cross sections for electrons in N_2.

Electron Energy eV	Cross Section 10^{-14} cm^2	Electron Energy eV	Cross Section 10^{-14} cm^2
10	10.2	30	11.1
12	10.4	50	9.3
15	11.1	75	7.7
17	11.6	100	6.6
20	12.0		
25	11.7		

Cont. Next Column

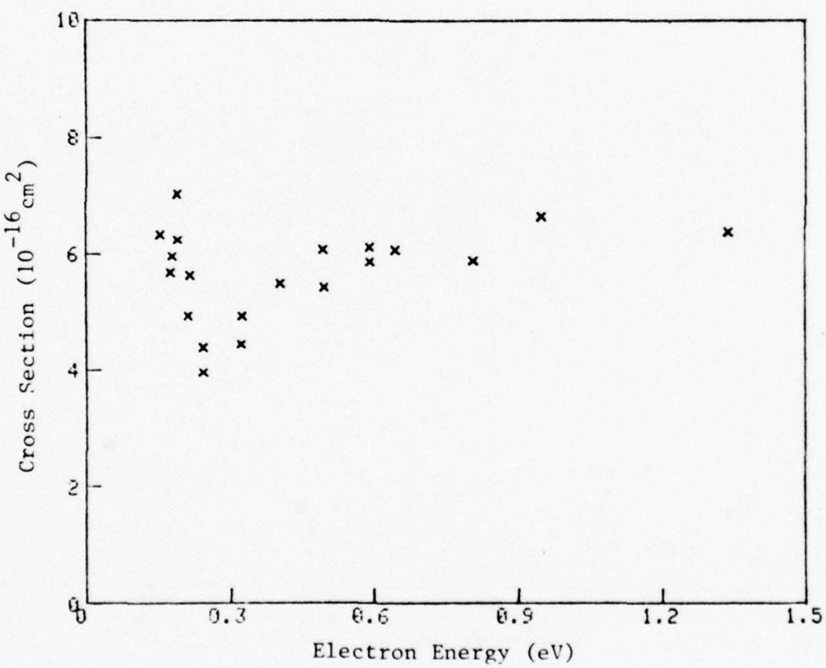


Reference: F. E. Spencer and A. V. Phelps, Proceedings of the 15th Symposium on the Engineering Aspects of Magnetohydrodynamics, Philadelphia, Pa., May, 1976. Paper IX.9.1

Tabular and Graphical Data C-1.18a. Total scattering cross sections for electrons in O_2.

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
0.187	7.04	0.242	4.38	0.592	6.11
0.154	6.34	0.242	3.96	0.592	5.86
0.191	6.25	0.320	4.44	0.646	6.08
0.179	5.97	0.323	4.92	0.807	5.88
0.175	5.69	0.403	5.49	0.949	6.65
0.215	5.63	0.495	5.43	1.34	6.39
0.210	4.92	0.493	6.08		

Cont. Next Column Cont. Next Column



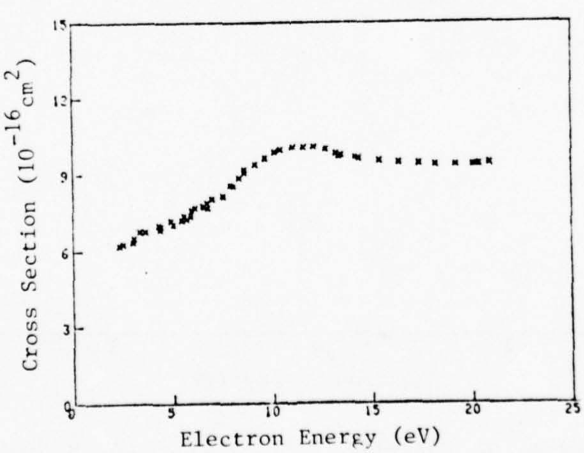
Reference: C. Ramsauer and R. Kollath, Ann. Phys. (Leipz.) 4, 149 (1930)

Tabular and Graphical Data C-1.18b. Total scattering cross sections for electrons in O_2.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
2.33	6.22	6.49	7.79	12.7	10.0
2.50	6.29	6.58	7.75	13.2	9.85
2.99	6.38	6.68	7.90	13.4	9.73
3.05	6.53	6.73	7.70	13.5	9.76
3.36	6.80	6.95	8.04	14.2	9.69
3.64	6.79	7.52	8.16	14.3	9.66
4.30	7.03	7.88	8.58	15.4	9.55
4.38	6.86	8.02	8.56	16.4	9.48
4.39	6.98	8.33	8.88	17.4	9.44
4.92	7.20	8.60	9.09	18.2	9.41
5.01	7.06	8.59	9.21	19.2	9.39
5.48	7.22	9.14	9.41	20.1	9.40
5.60	7.38	9.64	9.65	20.3	9.41
5.70	7.28	10.1	9.89	20.4	9.41
5.91	7.36	10.4	9.98	20.9	9.45
5.90	7.47	11.0	10.1		
5.93	7.62	11.6	10.1		
6.11	7.69	12.1	10.1		

Cont. Next Column

Cont. Next Column



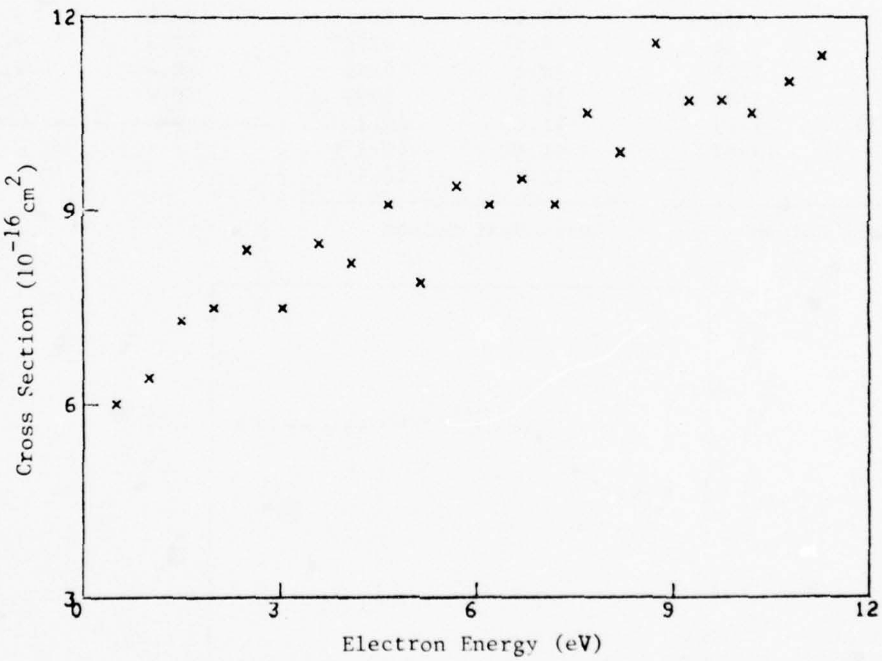
Reference: A. Salop and H. H. Nakano, Phys. Rev. A 2, 127 (1970)

Tabular and Graphical Data C-1.18c. Total scattering cross sections for electrons in O_2.

Electron Energy eV	Cross Section $10^{-16} cm^2$
11.3	11.4
10.8	11.0
10.2	10.5
9.75	10.7
9.25	10.7
8.75	11.6
8.20	9.90
7.70	10.5
7.20	9.10
6.70	9.50
6.20	9.10
5.70	9.40
5.15	7.90
4.65	9.10
4.10	8.20
3.60	8.50
3.05	7.50
2.50	8.40
2.00	7.50
1.50	7.30
1.000	6.40
0.500	6.00

Cont. Next Column

Cont. Next Column



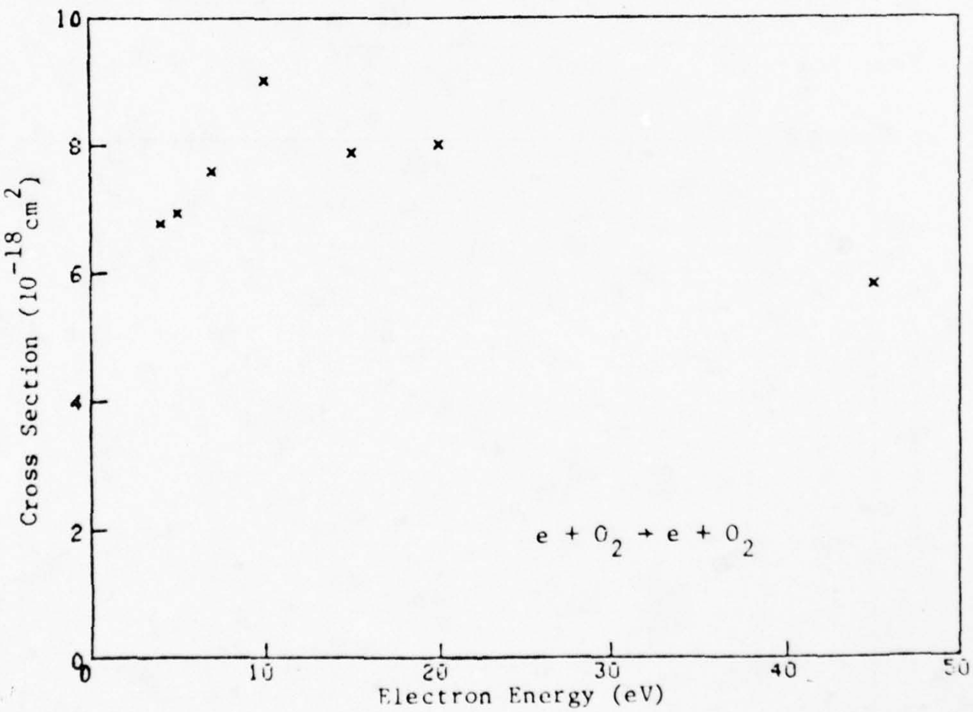
Reference: G. Sunshine, B. B. Aubrey, and B. Bederson, Phys. Rev. 154, 1 (1967)

Tabular and Graphical Data C-1.19. Elastic scattering cross sections for electrons in O_2.

$$e + O_2 \rightarrow e + O_2$$

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
4.0	6.78	15	7.89
5.0	6.95	20	8.02
7.0	7.60	45	5.82
10.0	9.03		

Cont. Next Column

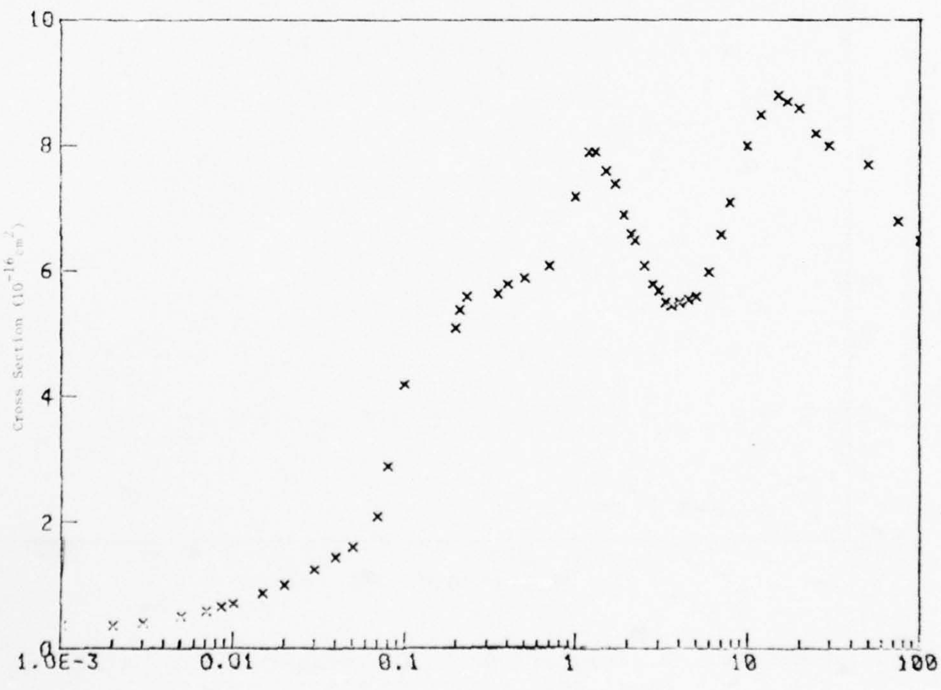


Reference: S. Trajmar, D. C. Cartwright and W. Williams, Phys. Rev. A 4, 1482 (1971)

Tabular and Graphical Data C-1.20. Momentum transfer cross sections for electrons in O_2.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0	0.35	0.23	5.6	4.0	5.5
0.0010	0.35	0.35	5.7	4.5	5.5
0.0020	0.36	0.40	5.8	5.0	5.6
0.0030	0.40	0.50	5.9	6.0	6.0
0.0050	0.50	0.70	6.1	7.0	6.6
0.0070	0.58	1.00	7.2	8.0	7.1
0.0085	0.64	1.2	7.9	10.0	8.0
0.010	0.70	1.3	7.9	12	8.5
0.015	0.87	1.5	7.6	15	8.8
0.020	0.99	1.7	7.4	17	8.7
0.030	1.2	1.9	6.9	20	8.6
0.040	1.4	2.1	6.6	25	8.2
0.050	1.6	2.2	6.5	30	8.0
0.070	2.1	2.5	6.1	50	7.7
0.080	2.9	2.8	5.8	75	6.8
0.10	4.2	3.0	5.7	100	6.5
0.20	5.1	3.3	5.5		
0.21	5.4	3.6	5.5		

Cont. Next Column   Cont. Next Column

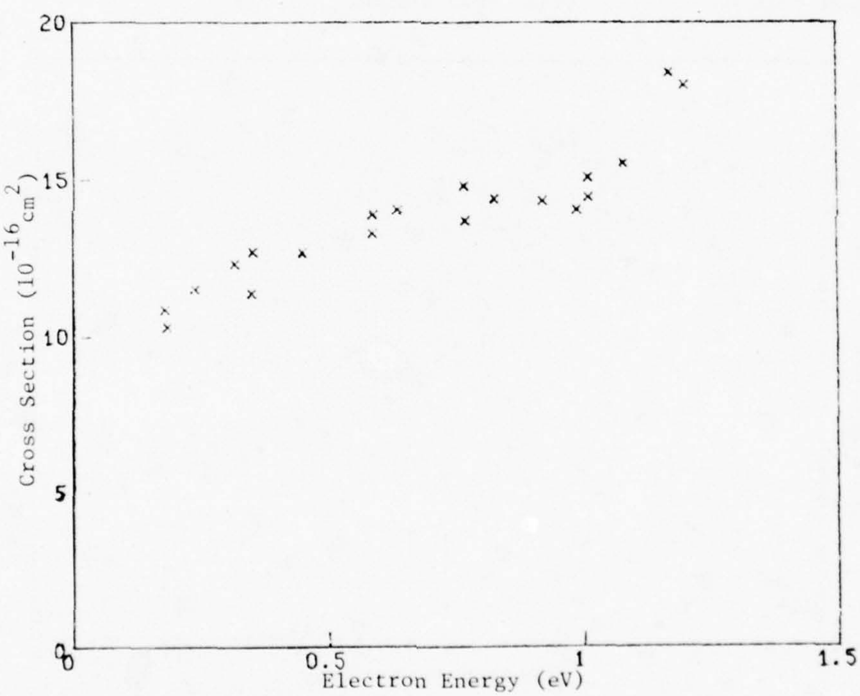


Reference: S. A. Lawton and A. V. Phelps, J. Chem. Phys. 69, 1055 (1978)

Tabular and Graphical Data C-1.21a. Total scattering cross sections for electrons in CO.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0.177	10.8	0.587	13.3	1.01	14.5
0.180	10.3	0.636	14.1	1.08	15.5
0.236	11.5	0.766	14.8	1.17	18.4
0.315	12.3	0.770	13.7	1.20	18.0
0.348	11.3	0.826	14.4		
0.352	12.7	0.920	14.3		
0.449	12.7	0.987	14.1		
0.587	13.9	1.01	15.1		

Cont. Next Column
Cont. Next Column

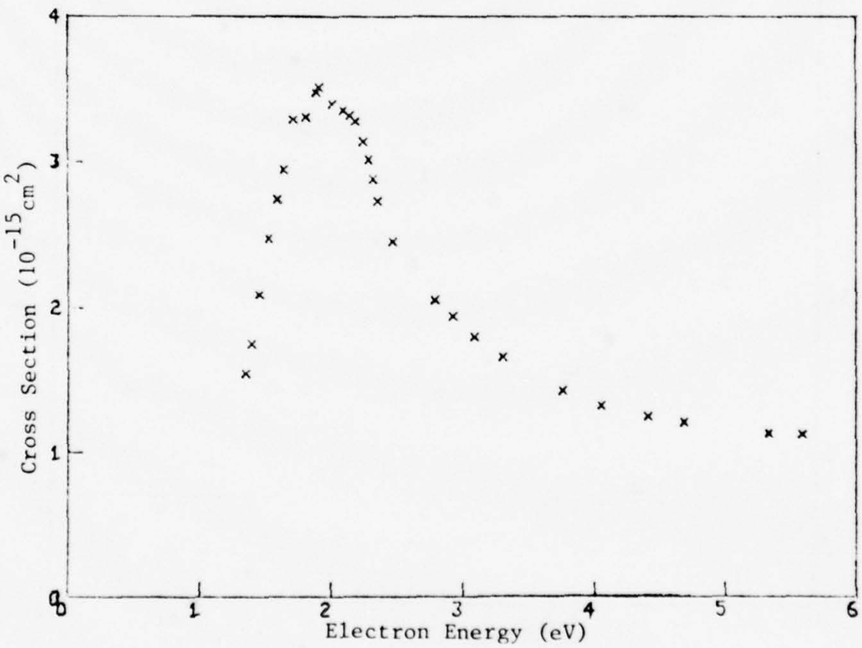


Reference: C. Ramsauer and R. Kollath, Ann. Phys. (Leipz.) 4, 91 (1930)

Tabular and Graphical Data C-1.21b. Total scattering cross sections for electrons in CO.

Electron Energy eV	Cross Section $10^{-15}cm^2$	Electron Energy eV	Cross Section $10^{-15}cm^2$	Electron Energy eV	Cross Section $10^{-15}cm^2$
1.34	1.55	2.01	3.40	2.79	2.05
1.39	1.75	2.09	3.35	2.93	1.94
1.45	2.09	2.14	3.32	3.10	1.80
1.52	2.47	2.18	3.28	3.31	1.66
1.59	2.75	2.25	3.14	3.75	1.43
1.63	2.95	2.28	3.02	4.05	1.33
1.71	3.29	2.31	2.89	4.41	1.25
1.81	3.31	2.35	2.74	4.69	1.21
1.89	3.48	2.46	2.46	5.34	1.13
1.91	3.51	2.47	2.46	5.59	1.13

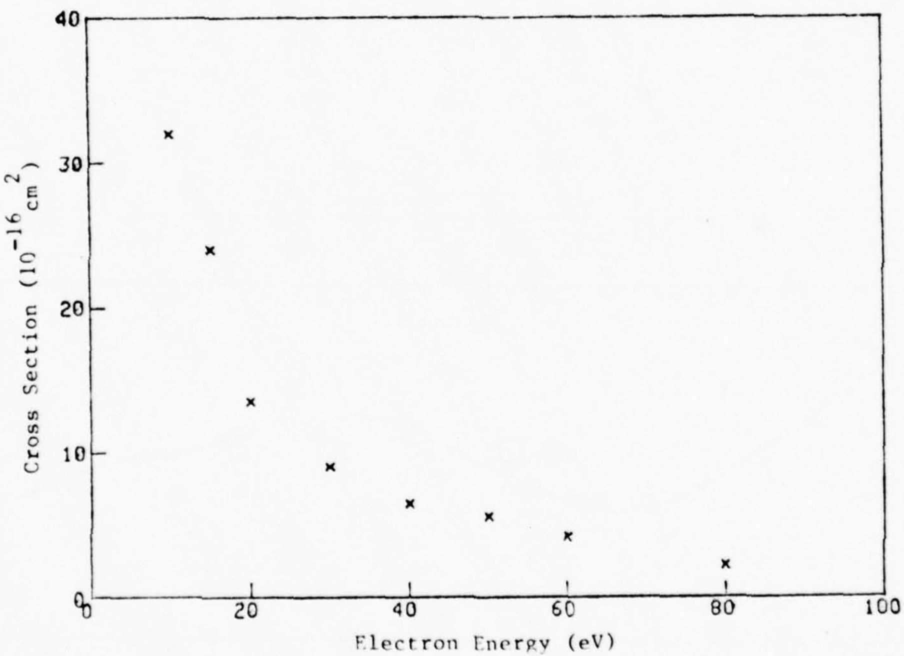
Cont. Next Column Cont. Next Column



Reference: C. Szmytkowski and M. Zubek, Chem. Phys. Lett. 57, 105 (1978)

Tabular and Graphical Data C-1.21c. Total scattering cross sections for electrons in CO.

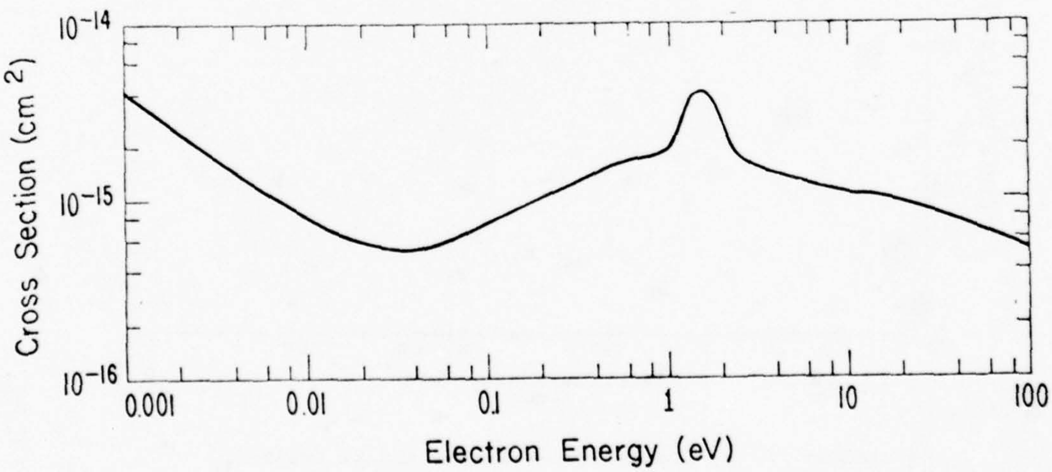
Electron Energy eV	Cross Section $10^{-16}cm^2$
10.0	32
15	24
20	14
30	9.0
40	6.4
50	5.5
60	4.1
80	2.1



Reference: D. G. Truhlar, W. Williams and S. Trajmar, J. Chem. Phys. 57, 4307 (1972)

Tabular and Graphical Data C-1.22. Momentum transfer cross sections for electrons in CO.

E (eV)	Q_m (10^{-16} cm^2)	E (eV)	Q_m (10^{-16} cm^2)	E (eV)	Q_m (10^{-16} cm^2)
0.0	60.0	0.25	11.2	3.3	14.6
0.0010	40.0	0.30	12.1	3.6	14.2
0.0020	25.0	0.35	13.0	4.0	13.8
0.0030	17.7	0.40	13.8	4.5	13.3
0.0050	12.3	0.50	15.4	5.0	12.9
0.0070	9.8	0.70	16.5	6.0	12.3
0.0085	8.6	1.00	18.5	7.0	11.8
0.0100	7.8	1.2	28.0	8.0	11.3
0.015	6.5	1.3	37.0	10.0	10.6
0.020	5.9	1.5	42.0	12.0	10.4
0.030	5.4	1.7	40.0	15.0	10.2
0.040	5.2	1.9	32.0	17.0	10.1
0.050	5.4	2.1	23.5	20.0	9.8
0.070	6.1	2.2	21.5	25.0	9.1
0.100	7.3	2.5	17.5	30.0	8.6
0.15	8.8	2.8	16.0	50.0	7.1
0.20	10.0	3.0	15.4	75.0	6.1
				100.0	5.5



Reference: J. Land, J. Appl. Phys. 49, 5716 (1978)

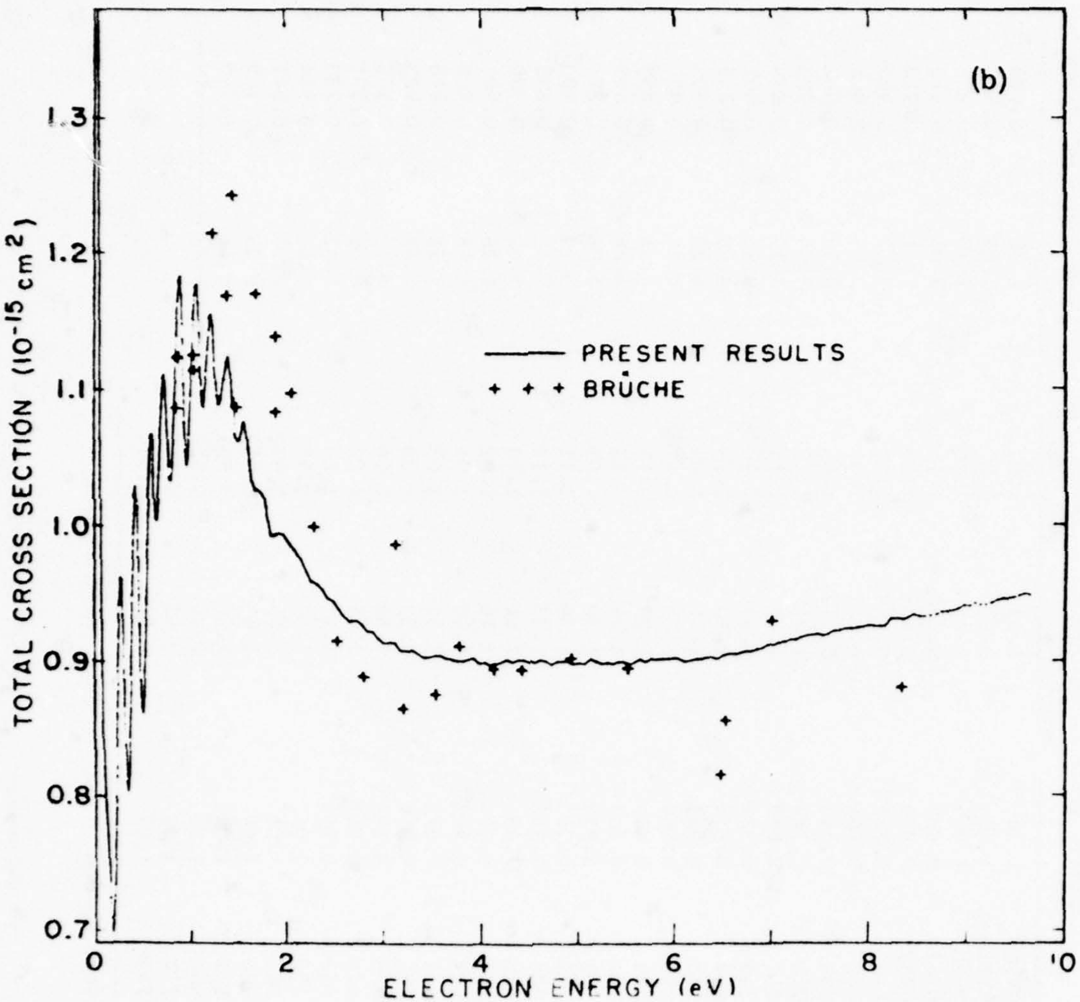
Tabular Data C-1.23. Total scattering cross sections for electrons in NO.

Electron Energy eV	Cross Section $10^{-15} cm^2$	Electron Energy eV	Cross Section $10^{-15} cm^2$	Electron Energy eV	Cross Section $10^{-15} cm^2$
0.0478	1.34	0.780	1.04	2.72	0.928
0.0521	1.20	0.827	1.07	2.83	0.920
0.0650	1.000	0.831	1.10	2.90	0.920
0.0747	0.899	0.848	1.15	3.00	0.913
0.0962	0.800	0.876	1.18	3.11	0.913
0.149	0.725	0.919	1.13	3.17	0.907
0.166	0.704	0.933	1.09	3.27	0.908
0.204	0.745	0.972	1.05	3.38	0.902
0.201	0.784	1.01	1.09	3.54	0.903
0.212	0.853	1.02	1.15	3.77	0.899
0.245	0.934	1.05	1.18	3.91	0.901
0.259	0.959	1.10	1.14	4.09	0.896
0.283	0.923	1.11	1.09	4.28	0.899
0.297	0.888	1.18	1.12	4.41	0.900
0.299	0.835	1.20	1.15	4.64	0.899
0.332	0.807	1.24	1.12	4.86	0.899
0.353	0.850	1.30	1.09	5.06	0.897
0.375	0.893	1.36	1.11	5.10	0.900
0.386	0.953	1.37	1.12	5.45	0.898
0.420	1.03	1.41	1.10	5.81	0.900
0.451	0.994	1.44	1.08	6.26	0.901
0.469	0.942	1.49	1.06	6.68	0.906
0.471	0.879	1.52	1.07	7.29	0.916
0.491	0.866	1.55	1.08	7.81	0.923
0.516	0.896	1.58	1.06	8.15	0.925
0.545	0.945	1.66	1.03	8.20	0.931
0.552	0.995	1.71	1.03	8.42	0.933
0.557	1.04	1.83	0.997	8.63	0.934
0.589	1.06	1.85	0.992	8.95	0.941
0.606	1.04	1.93	0.993	9.28	0.945
0.631	1.01	2.07	0.981	9.59	0.949
0.660	1.05	2.26	0.957		
0.714	1.11	2.42	0.948		
0.745	1.07	2.59	0.933		

Cont. Next Column

Cont. Next Column

Reference: A. Zecca, I. Lazzizzara, M. Krauss, and C. E. Kuyatt, J. Chem. Phys. 61, 4560 (1974)



Graphical Data C-1.23. Total scattering cross sections for electrons in NO.

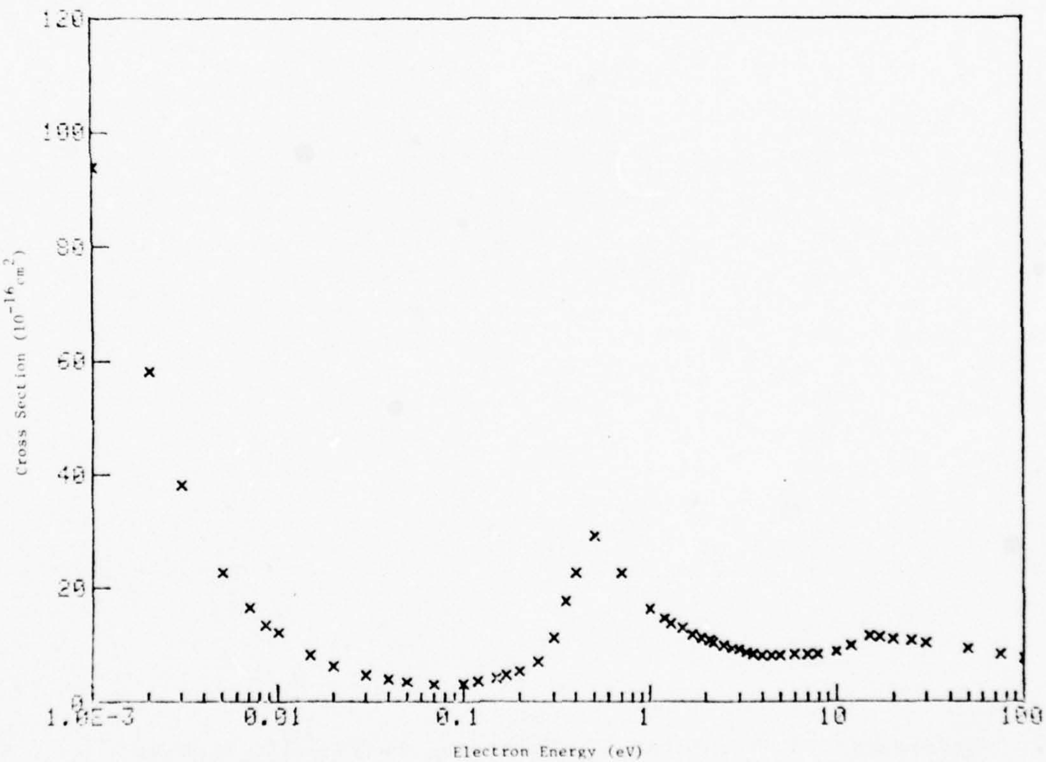
Tabular Data C-1.24. Elastic scattering cross sections for electrons in NO.

Electron Energy eV	Cross Section $10^{-16} cm^2$
0.43	19
0.60	17

Reference: J. Reinhardt, F. Gresteau, R. I. Hall, A Huetz and M. Tronc, ICPEAC IX Abstracts 1, 271 (1975)

Tabular and Graphical Data C-1.25. Momentum transfer cross sections for electrons in NO.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0	120	0.20	5.30	3.3	8.60
0.0010	94.0	0.25	7.00	3.6	8.30
0.0020	58.0	0.30	11.1	4.0	8.10
0.0030	38.0	0.35	17.5	4.5	8.10
0.0050	22.5	0.40	22.5	5.0	8.10
0.0070	16.3	0.50	29.0	6.0	8.20
0.0085	13.3	0.70	22.5	7.0	8.30
0.010	12.0	1.0	16.1	8.0	8.40
0.015	8.10	1.2	14.5	10.0	8.80
0.020	6.20	1.3	13.7	12	9.90
0.030	4.65	1.5	12.9	15	11.5
0.040	3.85	1.7	11.7	17	11.4
0.050	3.40	1.9	11.1	20	11.0
0.070	3.00	2.1	10.7	25	10.7
0.10	3.10	2.2	10.4	30	10.3
0.12	3.45	2.5	9.90	50	9.20
0.15	4.05	2.8	9.30	75	8.20
0.17	4.55	3.0	9.10	100	7.50
Cont. Next Column		Cont. Next Column			



Reference: F. E. Spencer and A. V. Phelps, Proceedings of the 15th Symposium on the Engineering Aspects of Magnetodydrodynamics, Philadelphia, Pa., May, 1976. Paper Ix.9.1

Tabular Data C-1.26a. Total scattering cross sections for electrons in CO_2.

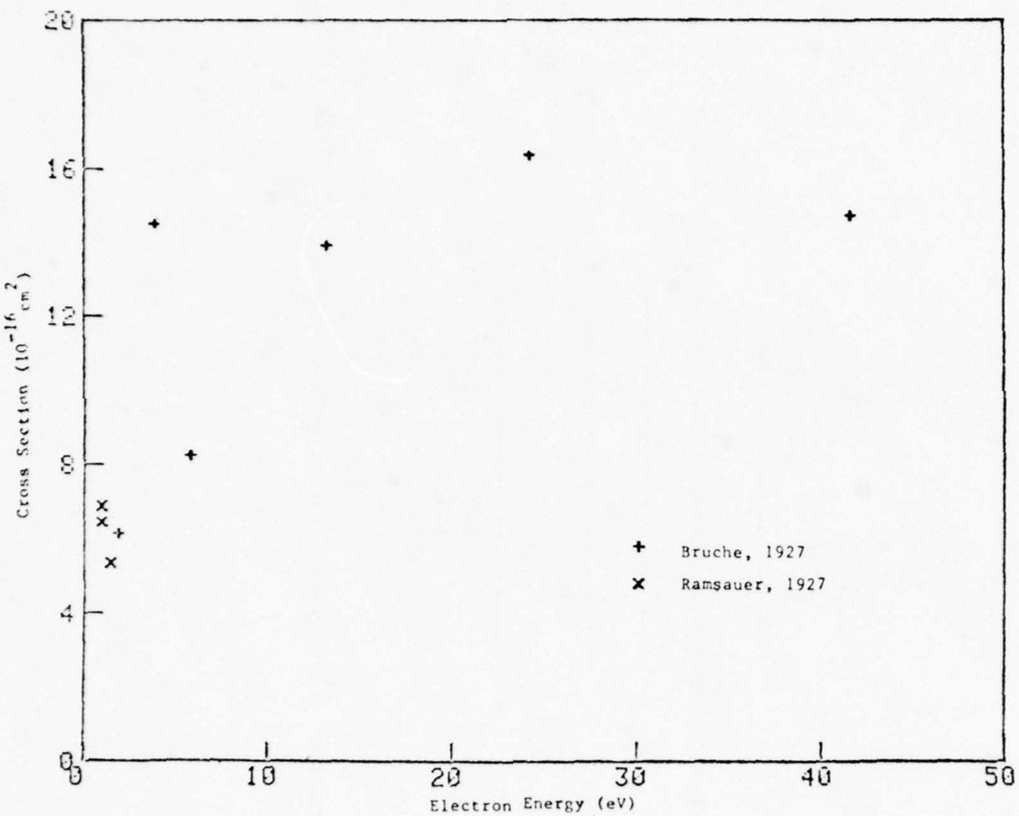
Electron Energy eV	Cross Section $10^{-16}cm^2$
1.80	6.14
3.76	14.5
5.76	8.23
13.2	13.9
24.2	16.4
41.7	14.8

Reference: E. Bruche, Ann. Phys. (Leipz.) 83, 1065 (1927).

Electron Energy eV	Cross Section $10^{-16}cm^2$
0.949	6.87
0.949	6.45
1.39	5.35

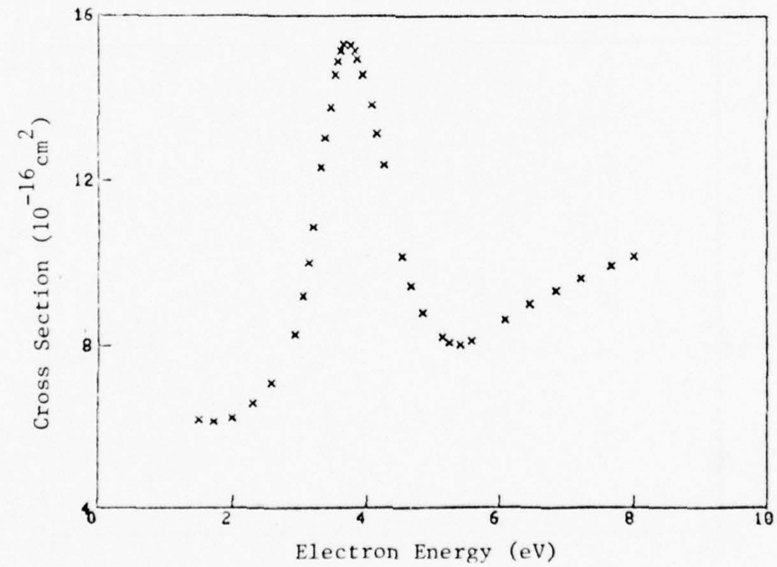
Reference: C. Ramsauer, Ann. Phys. (Leipz.) 83, 1129 (1927).

Graphical Data C-1.26a. Total scattering cross sections for electrons in CO_2.



Tabular and Graphical Data C-1.26b. Total scattering cross sections for electrons in CO_2.

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
1.51	6.18	3.53	14.6	4.67	9.45
1.72	6.12	3.56	14.9	4.83	8.81
1.99	6.20	3.61	15.2	5.14	8.21
2.29	6.57	3.65	15.3	5.25	8.08
2.57	7.08	3.76	15.3	5.41	8.02
2.92	8.27	3.82	15.2	5.59	8.11
3.05	9.22	3.85	15.0	6.08	8.63
3.13	10.0	3.94	14.6	6.44	9.01
3.19	10.9	4.06	13.9	6.84	9.35
3.31	12.3	4.16	13.2	7.21	9.65
3.38	13.1	4.27	12.4	7.67	9.96
3.45	13.8	4.53	10.2	8.01	10.2
Cont. Next Column		Cont. Next Column			



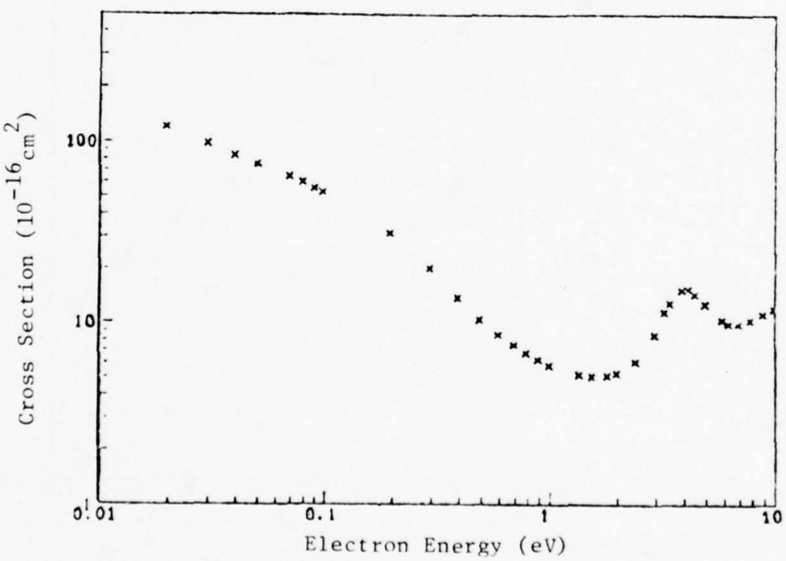
Reference: C. Szmytkowski and M. Zubek, Chem. Phys. Lett. 57, 105 (1978)

Tabular and Graphical Data C-1.27a. Momentum transfer cross sections for electrons in CO_2.

Electron Energy (eV)	Cross Section ($10^{-16}cm^2$)
0.0099	173
0.020	121
0.030	97.9
0.039	84.3
0.050	75.5
0.069	64.5
0.079	60.1
0.089	55.7
0.097	52.8
0.20	31.3
0.29	20.2
0.39	13.8
0.49	10.4
0.59	8.53
0.69	7.48
0.78	6.78
0.88	6.21
0.99	5.77
1.3	5.13
1.5	5.01
1.8	5.04
2.0	5.19
2.4	6.07
2.9	8.59
3.2	11.4
3.4	12.8
3.9	15.3
4.1	15.4
4.4	14.5
4.9	12.8
5.9	10.4
6.3	9.91
6.9	9.93
7.8	10.4
8.8	11.2
9.8	12.0
11	12.7

Cont. Next Column

Cont. Next Column

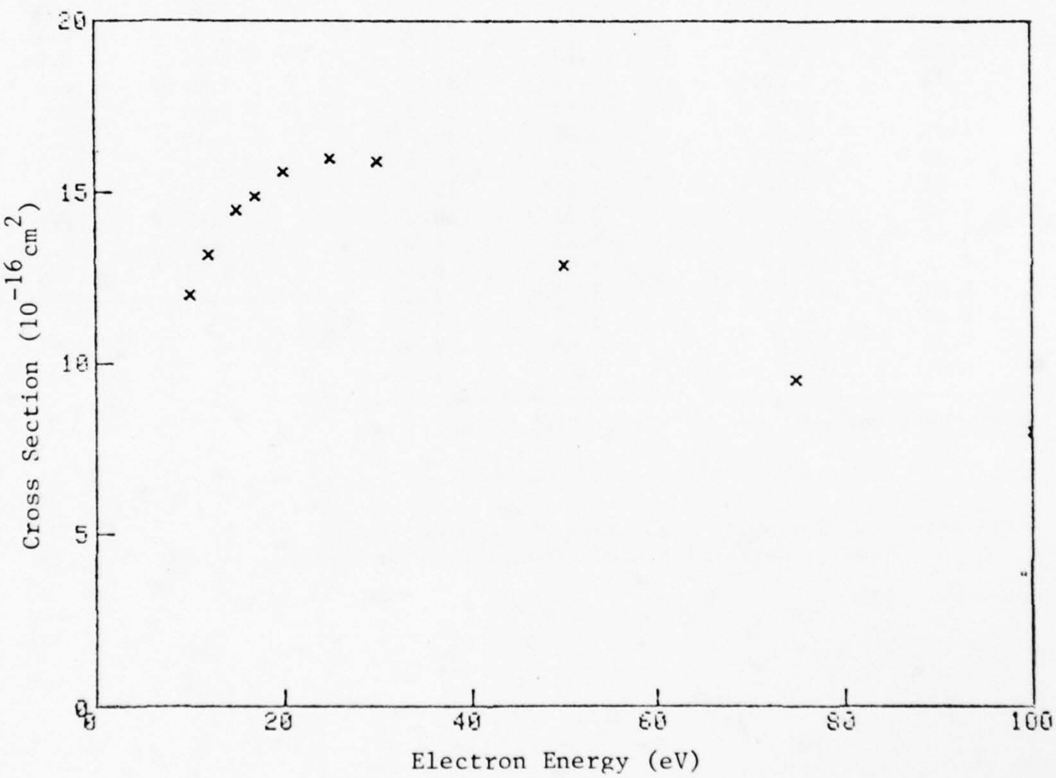


Reference: Y. Itikawa, At. Data and Nuc. Data Tables 21, 69 (1978)

Tabular and Graphical Data C-1.27b. Momentum transfer cross sections for electrons in CO_2.

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
10	12.0	25	16.0
12	13.2	30	15.9
15	14.5	50	12.9
17	14.9	75	9.5
20	15.6	100	8.0

Cont. Next Column



Reference: F. E. Spencer and A. V. Phelps, Proceedings of the 15th Symposium on the Engineering Aspects of Magnetohydrodynamics, Philadelphia, Pa., May, 1976. Paper IX.9.1

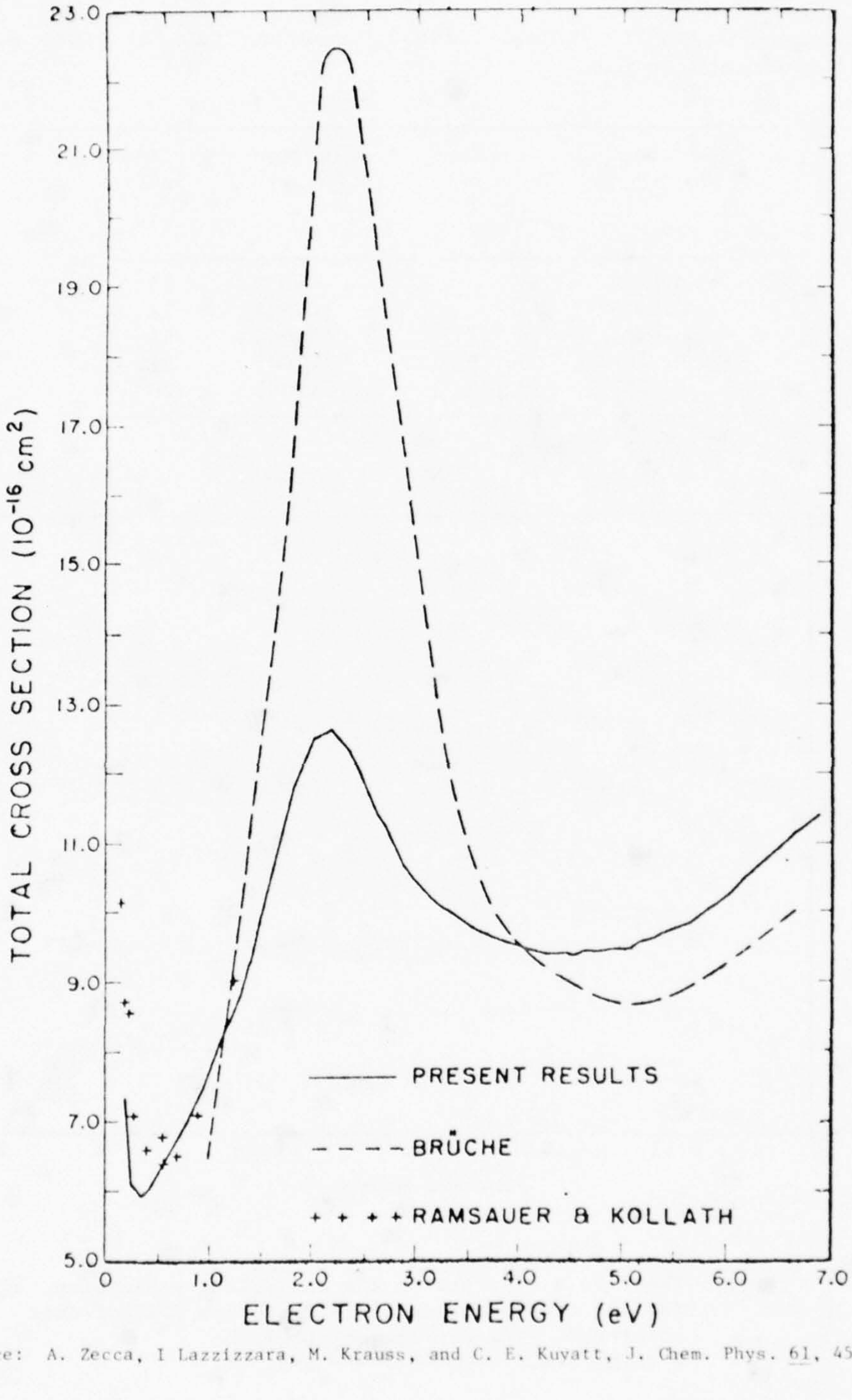
Tabular Data C-1.28. Total scattering cross sections for electrons in N_2O.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0.195	7.33	1.89	12.1	4.34	9.41
0.224	6.75	1.97	12.3	4.45	9.41
0.242	6.24	2.04	12.5	4.53	9.39
0.245	6.11	2.11	12.6	4.58	9.41
0.290	6.02	2.19	12.6	4.64	9.46
0.349	5.94	2.23	12.6	4.77	9.44
0.403	5.98	2.31	12.5	4.91	9.46
0.428	6.04	2.36	12.4	5.04	9.46
0.518	6.26	2.44	12.1	5.15	9.56
0.651	6.65	2.49	11.9	5.29	9.61
0.790	6.97	2.57	11.7	5.39	9.68
0.902	7.36	2.63	11.4	5.57	9.80
1.02	7.71	2.67	11.3	5.66	9.86
1.15	8.22	2.74	11.2	5.81	10.0
1.21	8.47	2.83	10.9	5.98	10.2
1.31	8.84	2.89	10.7	6.15	10.5
1.38	9.17	3.03	10.4	6.32	10.7
1.41	9.34	3.21	10.1	6.53	11.0
1.45	9.56	3.33	10.00	6.67	11.2
1.48	9.75	3.42	9.90	6.83	11.3
1.54	10.1	3.54	9.78	6.91	11.4
1.60	10.5	3.69	9.65		
1.68	10.9	3.82	9.58		
1.78	11.5	3.98	9.52		
1.84	11.8	4.20	9.44		

Cont. Next Column

Cont. Next Column

Reference: A. Zecca, I. Lazzizzara, M. Krauss, and C. E. Kuyatt, J. Chem. Phys. 61, 4560 (1974)



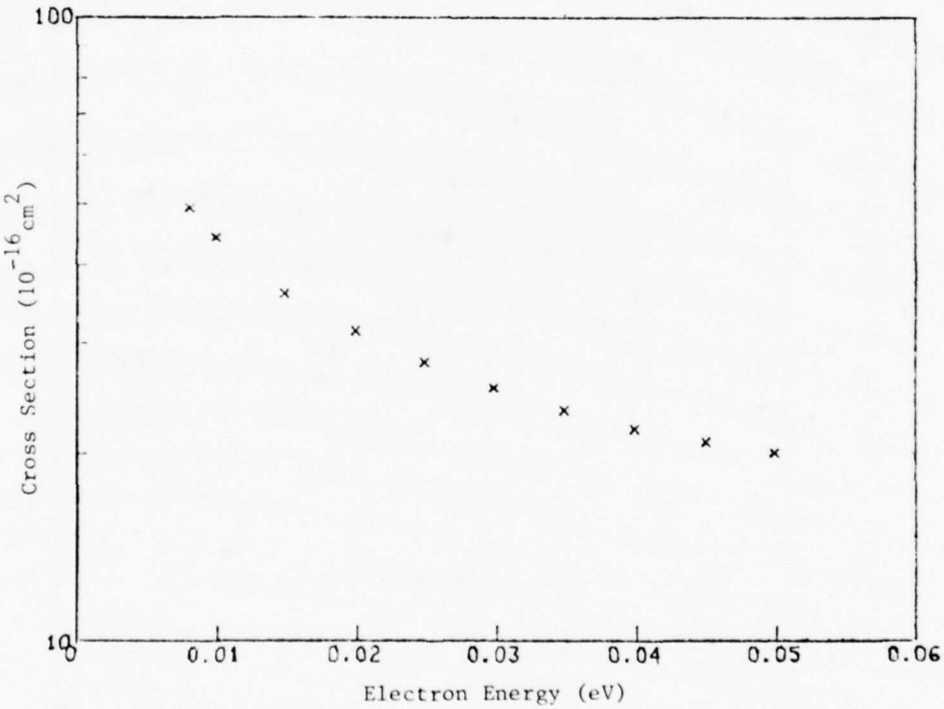
Reference: A. Zecca, I Lazzizzara, M. Krauss, and C. E. Kuyatt, J. Chem. Phys. 61, 4560 (1974)

Graphical Data C-1.28. Total scattering cross sections for electrons in N_2O.

Tabular and Graphical Data C-1.29a. Momentum transfer cross section for electrons in N_2O.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0.0080	49	0.030	25
0.0099	44	0.035	23
0.015	36	0.040	22
0.020	31	0.045	21
0.025	28	0.050	20

Cont. Next Column



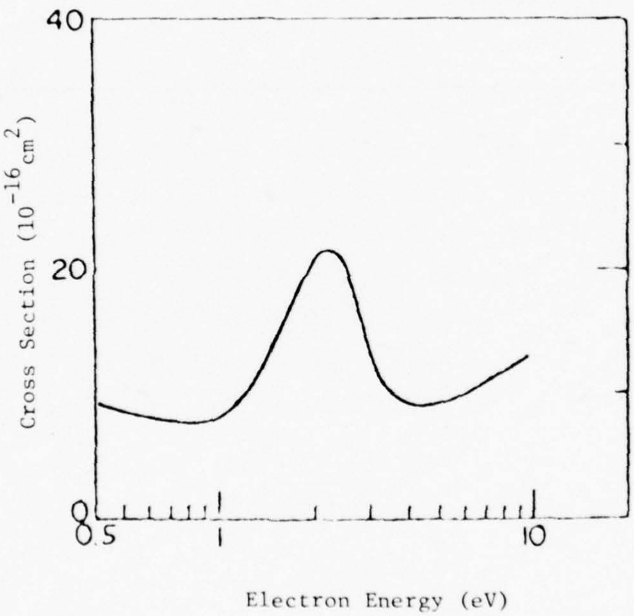
Note: There is a misprint in the analytical expression for the cross section for N_2O on page 2089 of this reference. The expression should be $\sigma\ (N_2O) = 4.4 \times 10^{-16}\ u^{-1/2}\ cm^2$.

Reference: J. L. Pack, R. E. Voshall and A. V. Phelps, Phys. Rev. 127, 2084 (1962)

Tabular and Graphical Data C-1.29b. Momentum transfer cross sections for electrons in N_2O.

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
0.50	8.47	2.0	20.9	3.1	12.5
0.86	7.50	2.1	21.5	3.4	10.2
0.98	7.86	2.2	21.5	4.0	9.17
1.2	9.87	2.4	20.9	4.5	9.03
1.5	14.1	2.5	20.1	5.0	9.15
1.7	18.1	2.8	16.0	9.5	13.0

Cont. Next Column   Cont. Next Column



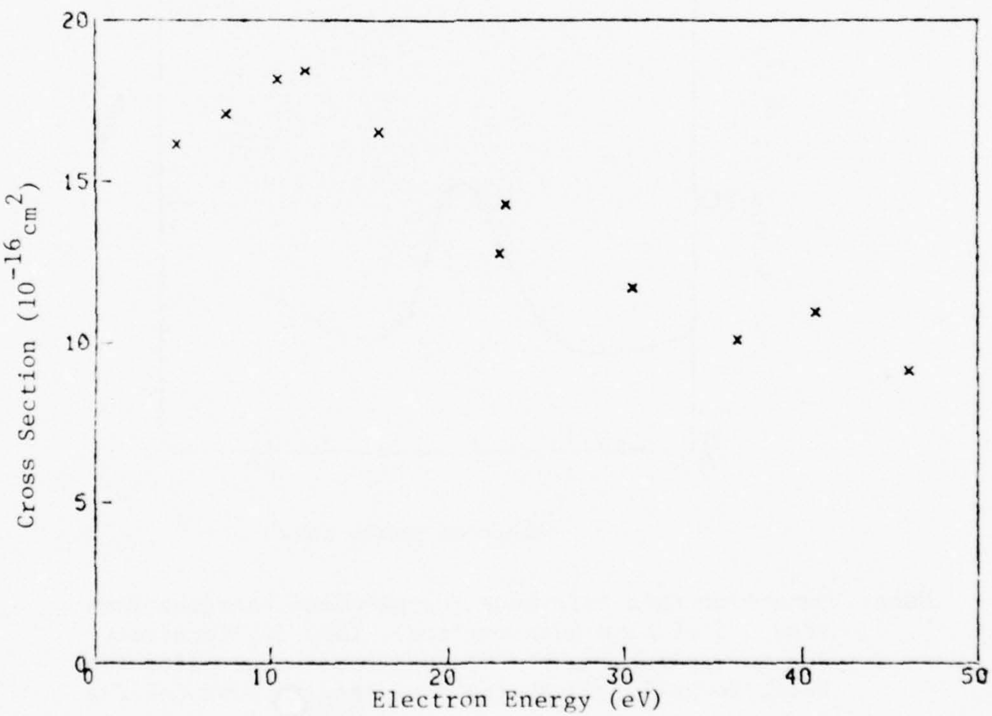
Note: Data from this reference for electron energies less than 0.5 eV have been omitted. They are incorrect due to application of the analytical expression from Pack, Voshall, and Phelps discussed in Data C-1.29a.

Reference: Y. Itikawa, Atomic Data 14, 1 (1974)

Tabular and Graphical Data C-1.30. Total scattering cross sections for electrons in H_2O.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
4.6	16	23	14
7.5	17	31	12
10	18	36	10
12	18	41	11
16	17	46	9.1
23	13		

Cont. Next Column



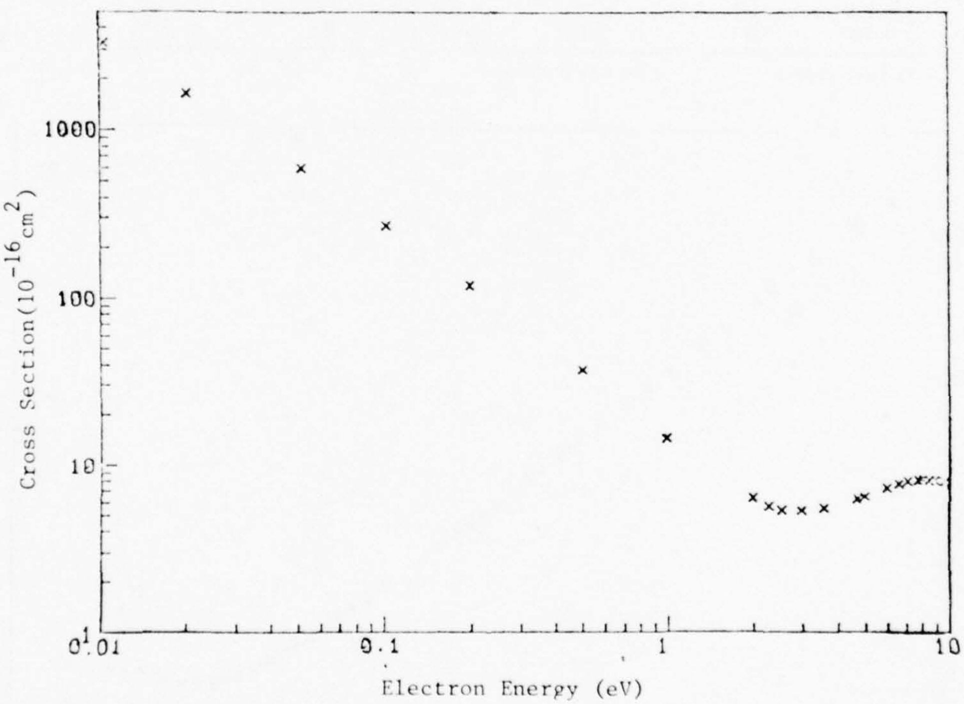
Reference. E. Bruche, Ann. Phys. (Leipz.) 2, 907 (1929)

Tabular and Graphical Data C-1.31a. Momentum transfer cross sections for electrons in H_2O.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0.010	3300	2.3	5.7	7.1	7.9
0.020	1600	2.5	5.4	7.7	8.1
0.052	600	3.0	5.3	8.0	8.2
0.10	270	3.6	5.5	8.4	8.1
0.20	120	4.7	6.2	8.8	8.1
0.50	37	5.0	6.4	9.5	7.9
1.00	14	6.0	7.3	10	7.6
2.0	6.3	6.6	7.6		

Cont. Next Column

Cont. Next Column

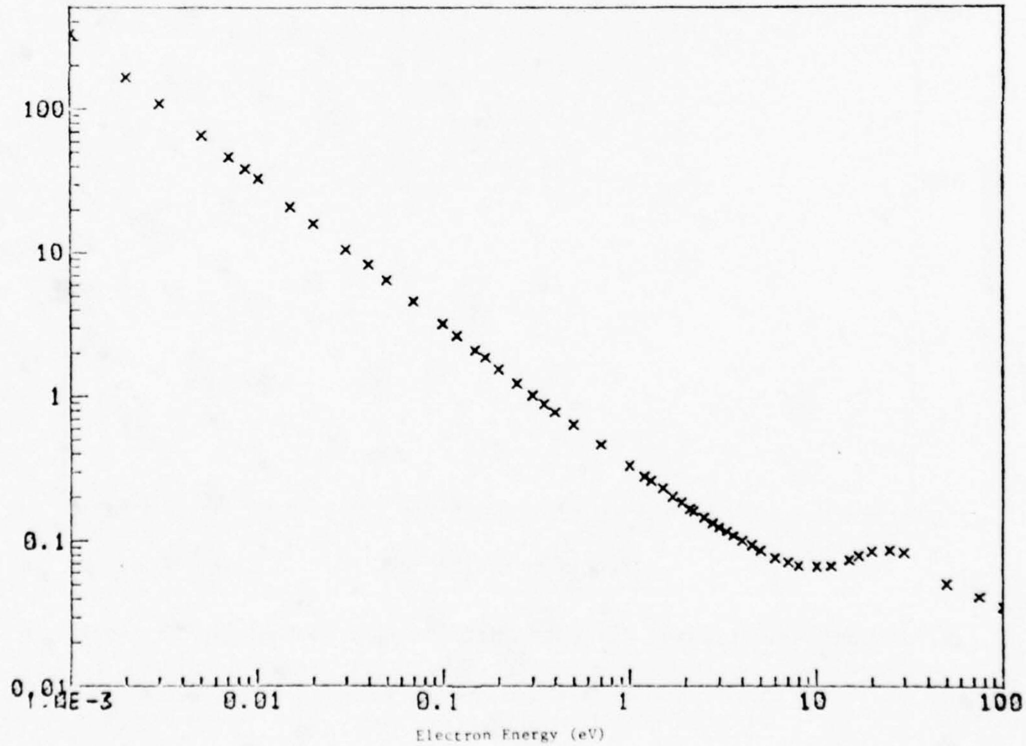


Reference: Y. Itikawa, At. Data and Nuc. Data Tables 21, 69 (1978)

Tabular and Graphical Data C-1.31b. Momentum transfer cross sections for electrons in H_2O.

Electron Energy eV	Cross Section $10^{-14}cm^2$	Electron Energy eV	Cross Section $10^{-14}cm^2$	Electron Energy eV	Cross Section $10^{-14}cm^2$
0	500	0.200	1.53	3.30	0.116
0.00100	330	0.250	1.24	3.60	0.108
0.00200	165	0.300	1.02	4.00	0.100
0.00300	110	0.350	0.890	4.50	0.0930
0.00500	66.0	0.400	0.780	5.00	0.0860
0.00700	47.1	0.500	0.635	6.00	0.0755
0.00850	38.8	0.700	0.463	7.00	0.0705
0.0100	33.0	1.00	0.331	8.00	0.0670
0.0150	21.2	1.20	0.280	10.00	0.0660
0.0200	16.1	1.30	0.260	12.0	0.0665
0.0300	10.6	1.50	0.229	15.0	0.0740
0.0400	8.30	1.70	0.200	17.0	0.0790
0.0500	6.50	1.90	0.182	20.0	0.0840
0.0700	4.56	2.10	0.166	25.0	0.0860
0.100	3.18	2.20	0.160	30.0	0.0830
0.120	2.65	2.30	0.144	50.0	0.0500
0.150	2.10	2.80	0.132	75.0	0.0410
0.170	1.87	3.00	0.124	100	0.0350

Cont. Next Column   Cont. Next Column

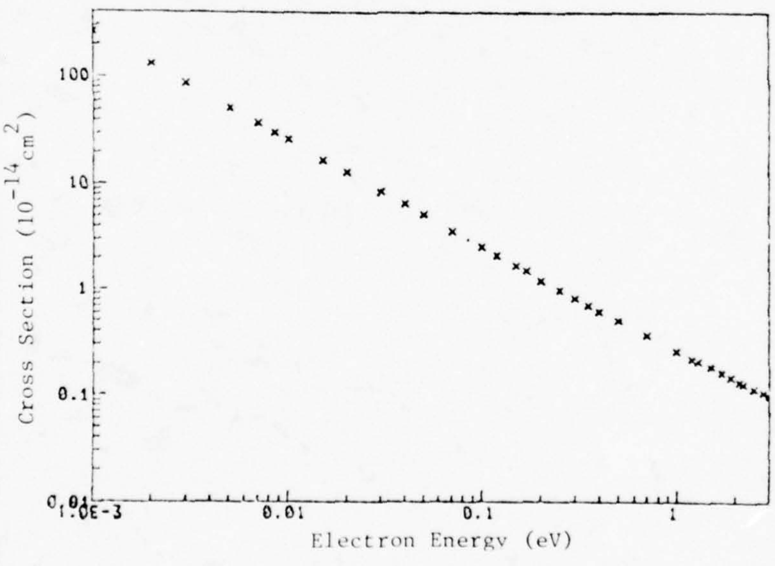


Reference: F. E. Spencer and A. V. Phelps, Proceedings of the 15th Symposium on the Engineering Aspects of Magnetohydrodynamics, Philadelphia, Pa., May, 1976. Paper IX.9.1

Tabular and Graphical Data C-1.32. Momentum transfer cross sections for electrons in OH.

Electron Energy eV	Cross Section $10^{-14}cm^2$	Electron Energy eV	Cross Section $10^{-14}cm^2$	Electron Energy eV	Cross Section $10^{-14}cm^2$
0	400	0.050	5.20	0.70	0.370
0.0010	264	0.070	3.60	1.0	0.260
0.0020	132	0.10	2.57	1.2	0.220
0.0030	88.0	0.12	2.14	1.3	0.210
0.0050	52.8	0.15	1.70	1.5	0.183
0.0070	38.0	0.17	1.51	1.7	0.161
0.0085	31.0	0.20	1.22	1.9	0.145
0.010	26.4	0.25	1.00	2.1	0.132
0.015	17.0	0.30	0.820	2.2	0.128
0.020	13.0	0.35	0.710	2.5	0.115
0.030	8.50	0.40	0.620	2.8	0.106
0.040	6.60	0.50	0.510	3.0	0.0990

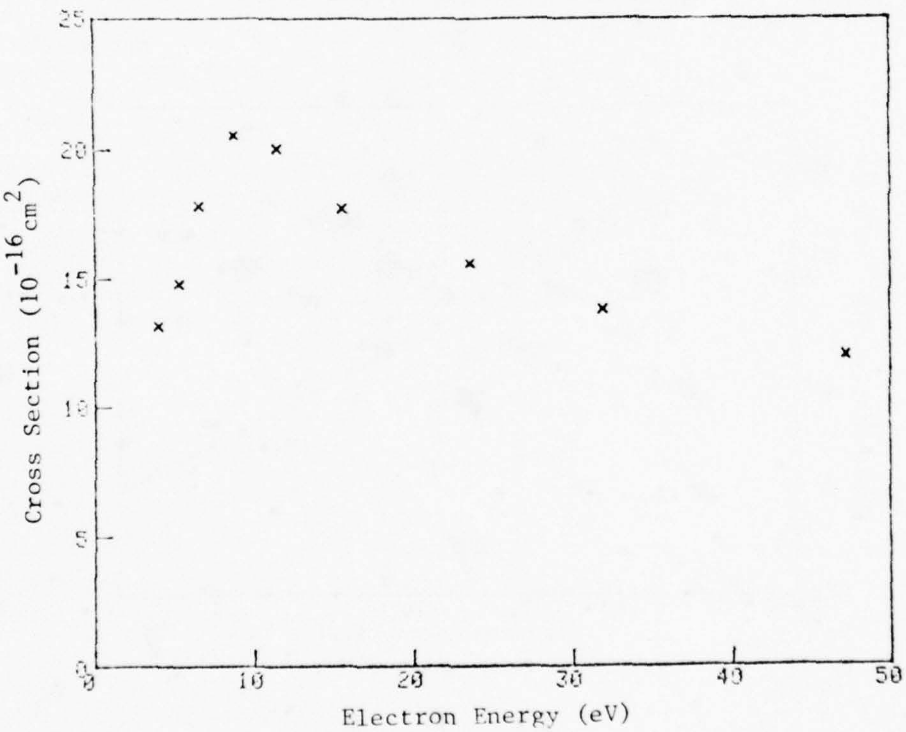
Cont. Next Column   Cont. Next Column



Reference: F. E. Spencer and A. V. Phelps, Proceedings of the 15th Symposium on the Engineering Aspects of Magnetohydrodynamics, Philadelphia, Pa., May, 1976. Paper IX.9.1

Tabular and Graphical Data C-1.33. Total scattering cross sections for electrons in NH_3.

Electron Energy eV	Cross Section $10^{-16}cm^2$
3.92	13.2
5.24	14.8
6.55	17.9
8.76	20.5
11.4	20.1
15.5	17.7
23.5	15.6
31.9	13.8
47.2	12.0



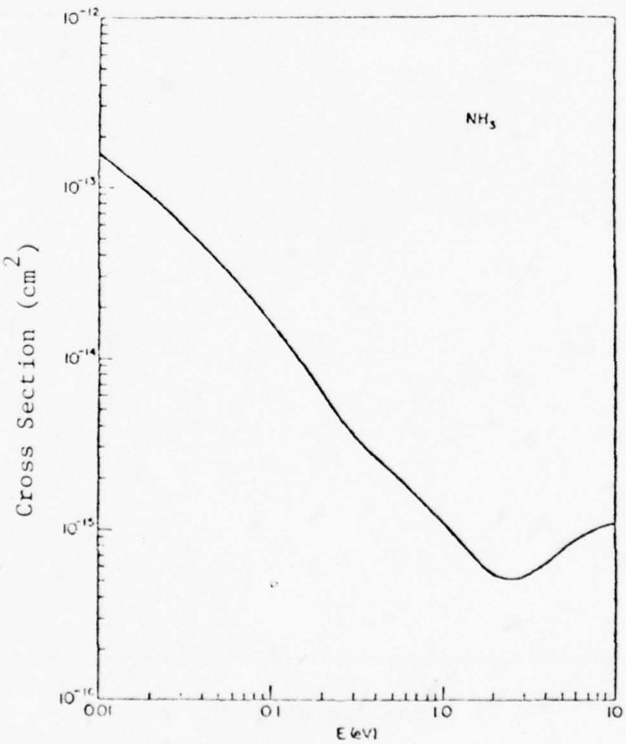
Reference: E. Bruche, Ann. Phys. (Leipz.) 1, 93 (1929)

Tabular and Graphical Data C-1.34. Momentum transfer cross sections for electrons in NH_3.

Electron Energy eV	Cross Section $10^{-16}cm^2$
0.0098	1570
0.021	870
0.053	345
0.096	168
0.19	67.1
0.49	21.7
1.0	10.9
1.6	6.25

Cont. Next Column

Electron Energy eV	Cross Section $10^{-16}cm^2$
2.0	5.42
2.3	5.07
3.0	5.41
4.0	6.42
4.9	7.67
7.0	9.81
9.8	11.0

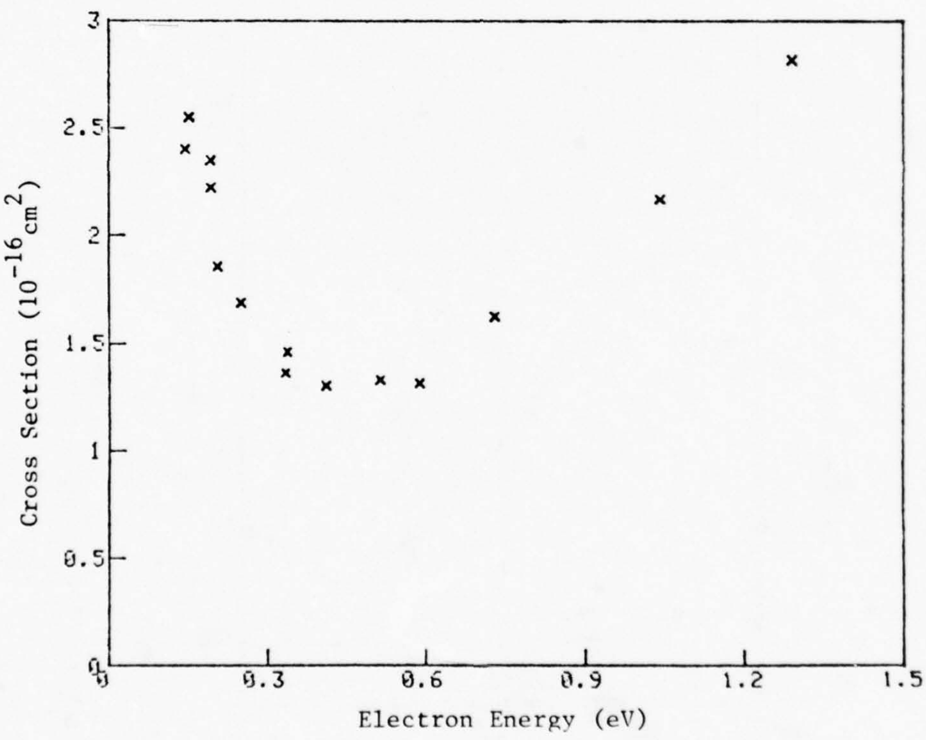


Reference: Y. Itikawa, Atomic Data 14, 1 (1974)

Tabular and Graphical Data C-1.35a. Total scattering cross sections for electrons in CH_4.

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
0.142	2.40	0.409	1.30
0.150	2.55	0.513	1.33
0.190	2.35	0.587	1.32
0.190	2.23	0.729	1.63
0.204	1.86	1.04	2.18
0.248	1.69	1.29	2.82
0.331	1.36		
0.335	1.46		

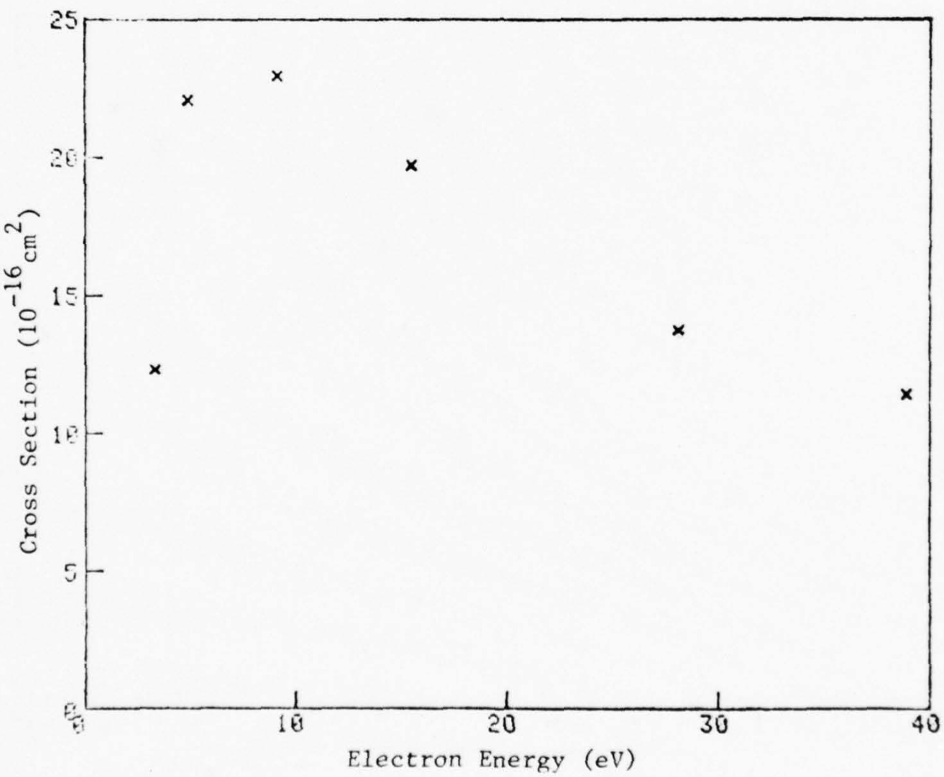
Cont. Next Column



Reference: C. Ramsauer and R. Kollath, Ann. Phys. (Leipz.) 4, 91 (1930)

Tabular and Graphical Data C-1.35b. Total scattering cross sections for electrons in CH_4.

Electron Energy eV	Cross Section $10^{-16} cm^2$
3.28	12.3
4.88	22.1
9.06	22.9
15.4	19.7
28.1	13.7
38.9	11.4

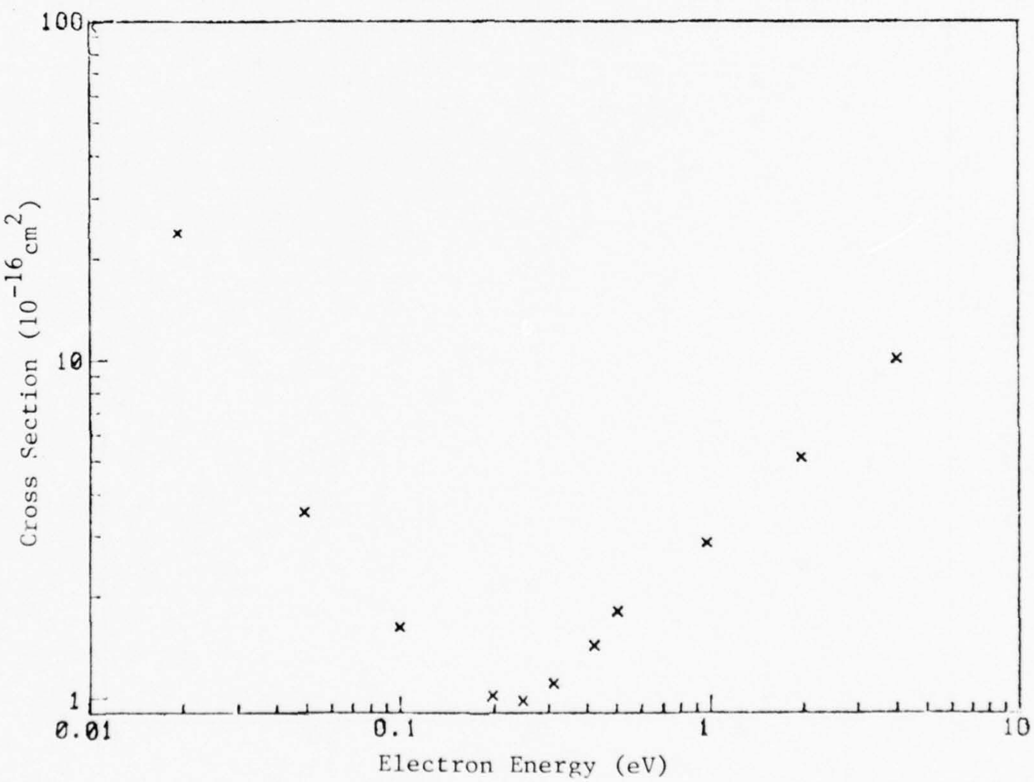


Reference: E. Bruche, Ann. Phys. (Leipz.) 4, 387 (1930)

Tabular and Graphical Data C-1.36. Momentum transfer cross sections for electrons in CH_4.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0.010	96.4	0.31	1.11
0.019	23.6	0.42	1.43
0.049	3.53	0.50	1.81
0.099	1.61	0.98	2.87
0.20	1.02	2.0	5.16
0.25	0.980	4.0	10.1

Cont. Next Column

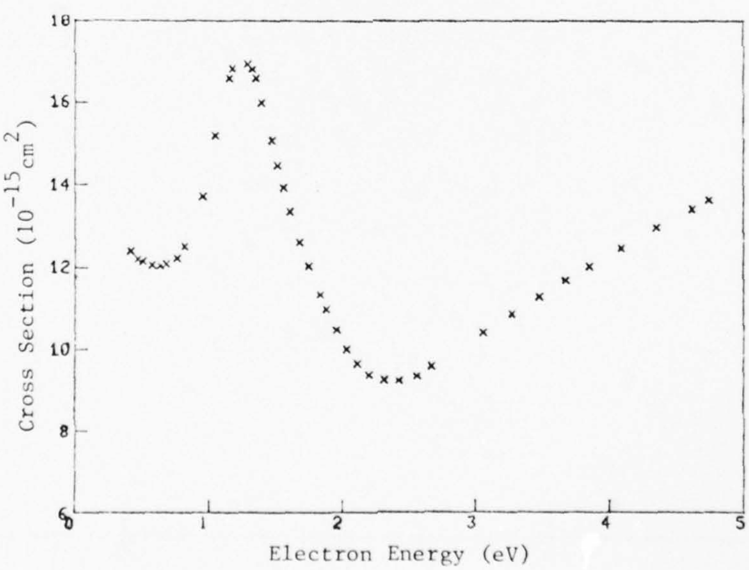


Reference: Y. Itikawa, Atomic Data 14, 1 (1974)

Tabular and Graphical Data C-1.37. Total scattering cross sections for electrons in OCS.

Electron Energy eV	Cross Section $10^{-15}cm^2$	Electron Energy eV	Cross Section $10^{-15}cm^2$	Electron Energy eV	Cross Section $10^{-15}cm^2$
0.407	12.4	1.32	16.8	2.20	9.39
0.463	12.2	1.35	16.6	2.31	9.25
0.463	12.2	1.39	16.0	2.42	9.24
0.502	12.2	1.47	15.1	2.56	9.35
0.570	12.0	1.51	14.5	2.67	9.59
0.632	12.0	1.56	13.9	3.05	10.4
0.679	12.1	1.60	13.4	3.27	10.9
0.755	12.2	1.68	12.6	3.47	11.3
0.813	12.5	1.75	12.0	3.67	11.7
0.951	13.7	1.83	11.3	3.85	12.0
1.05	15.2	1.88	11.0	4.09	12.5
1.15	16.6	1.96	10.5	4.35	13.0
1.17	16.8	2.03	10.0	4.62	13.4
1.29	16.9	2.12	9.65	4.74	13.6

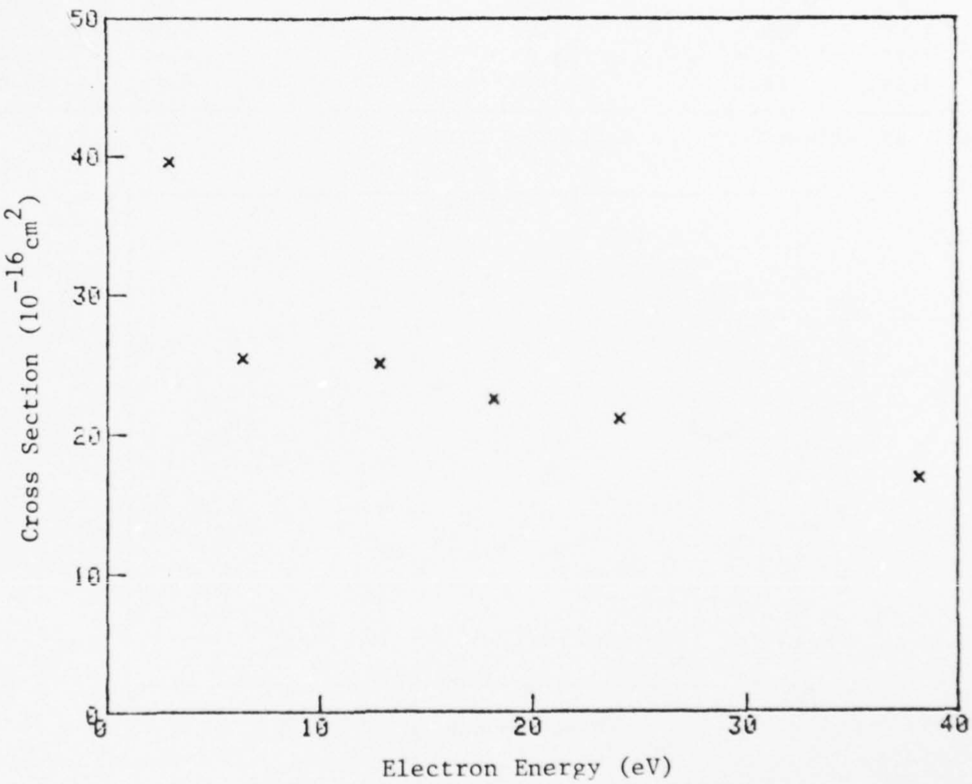
Cont. Next Column   Cont. Next Column



Reference: C. Szmytkowski and M. Zubek, Chem. Phys. Lett. 57, 105 (1978)

Tabular and Graphical Data C-1.38. Total scattering cross sections for electrons in C_2H_2.

Electron Energy eV	Cross Section $10^{-16}cm^2$
2.92	39.6
6.35	25.4
12.8	25.0
18.2	22.5
24.1	21.1
38.2	16.9

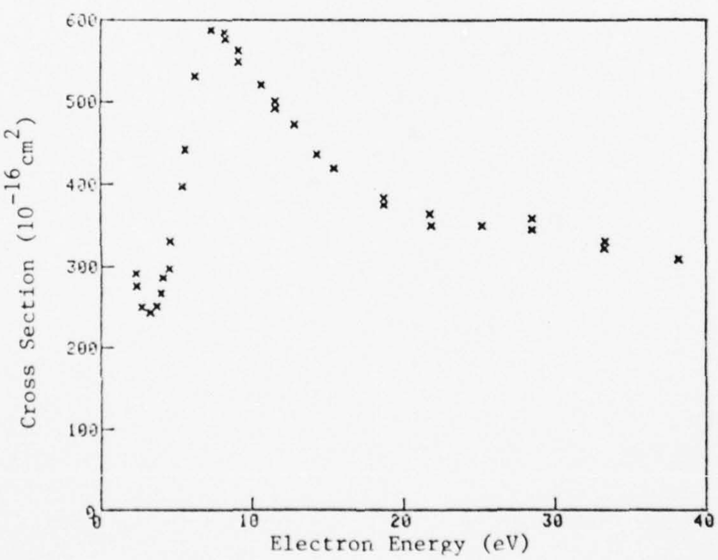


Reference: E. Bruche, Ann. Phys. (Leipz.) 2, 909 (1929)

Tabular and Graphical Data C-1.39. Total scattering cross sections for electrons in Cl_2.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
2.25	291	7.24	588	18.7	375
2.31	276	8.12	585	21.7	364
2.69	249	8.18	577	21.8	350
3.24	243	9.06	563	25.2	350
3.65	251	9.06	549	28.5	344
3.92	267	10.6	521	28.5	358
4.04	286	11.5	501	33.4	330
4.45	297	11.5	493	33.3	322
4.54	330	12.8	473	38.2	308
5.38	398	14.3	437		
5.57	442	15.4	420		
6.20	532	18.7	384		

Cont. Next Column   Cont. Next Column

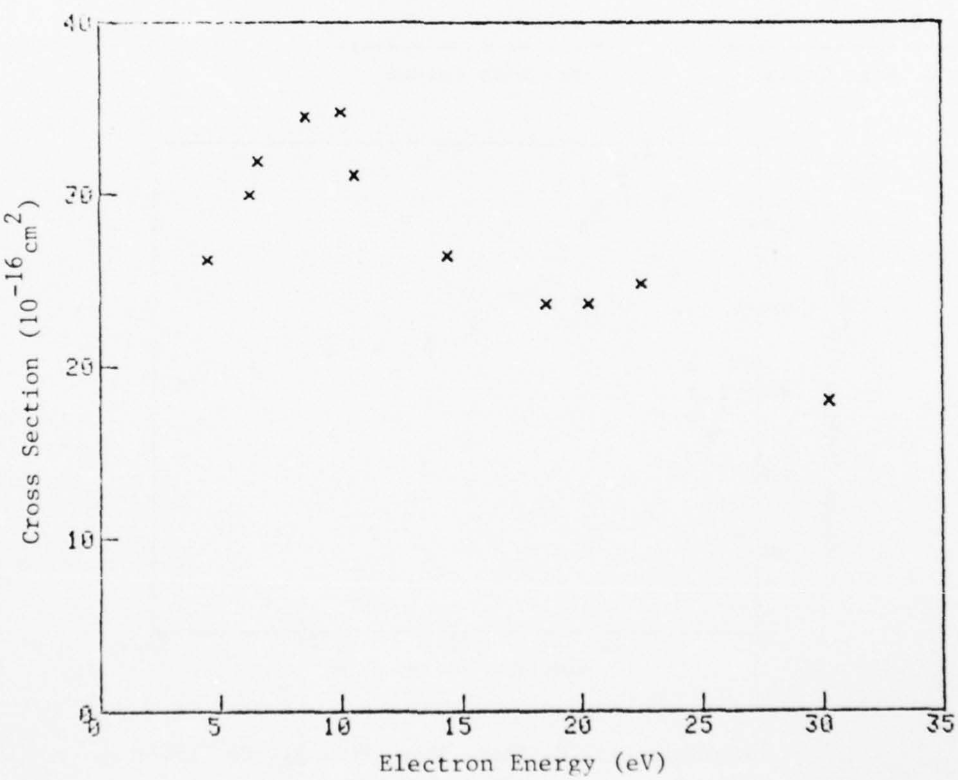


Reference: J. B. Fisk, Phys. Rev. 51, 25 (1937)

Tabular and Graphical Data C-1.40. Total scattering cross sections for electrons in HCl.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
4.45	26.1	14.4	26.4
6.20	30.0	18.5	23.5
6.55	32.0	20.3	23.5
8.53	34.5	22.5	24.8
9.99	34.8	30.3	17.9
10.5	31.1		

Cont. Next Column



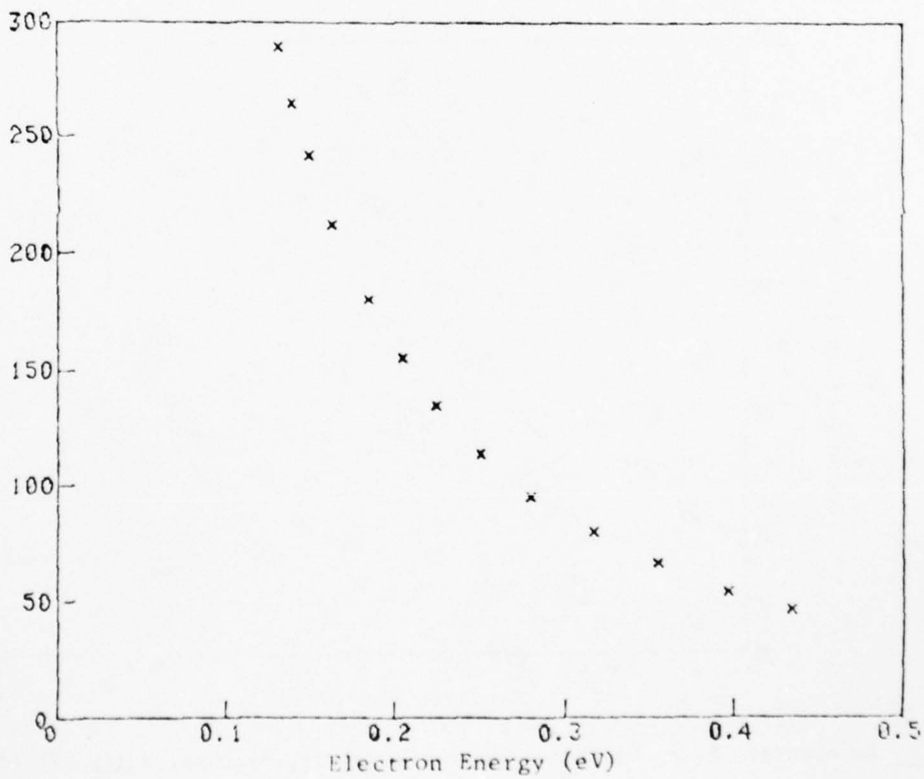
Reference: E. Bruche, Ann. Phys. (Leipz.) 82, 25 (1926)

Tabular and Graphical Data C-1.41a. Elastic scattering cross sections for electrons in HCl.

$$e + HCl \rightarrow e + HCl$$

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
0.13	290	0.25	114
0.14	265	0.28	95.1
0.15	242	0.32	79.5
0.16	213	0.36	66.5
0.18	181	0.40	54.5
0.21	156	0.43	46.6
0.22	135		

Cont. Next Column

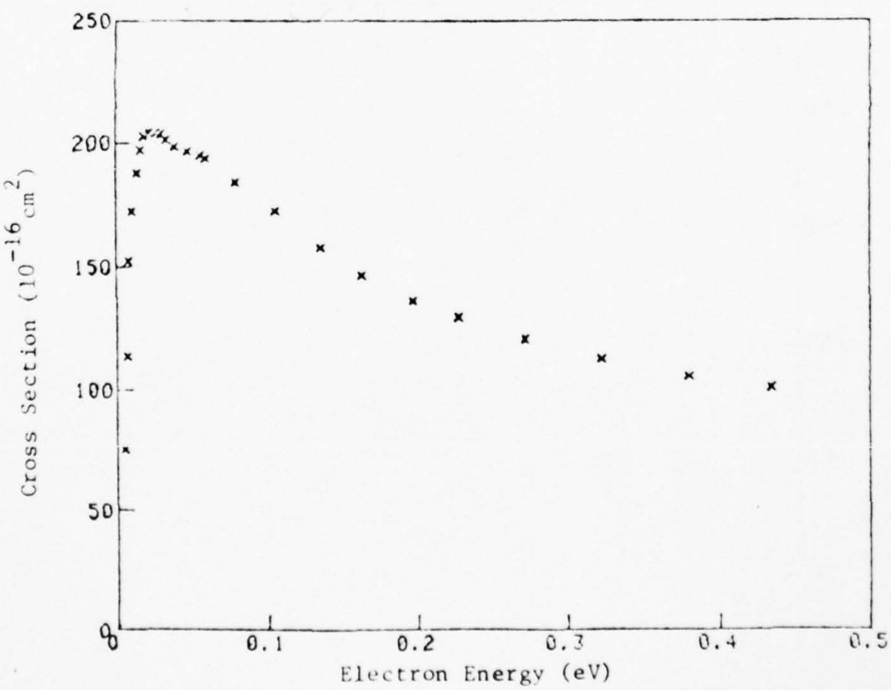


Reference: F. A. Gianturco and N. K. Rahman, J. Phys. B 11, 727 (1978)

Tabular and Graphical Data C-1.41b. Rotational excitation cross sections for electrons in HCl (rotational transition is j = 0 to j = 1).

$$e + HCl\ (j = 0) \rightarrow e + HCl\ (j = 1)$$

tron rgy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
0.0044	75.6	0.030	204	0.16	147
0.0063	114	0.033	201	0.20	136
0.0073	153	0.038	198	0.23	130
0.0098	172	0.047	196	0.27	120
0.014	188	0.055	195	0.32	112
0.016	197	0.058	193	0.38	105
0.018	203	0.078	184	0.43	101
0.022	204	0.10	172		
0.026	204	0.13	157		
Cont. Next Column		Cont. Next Column			



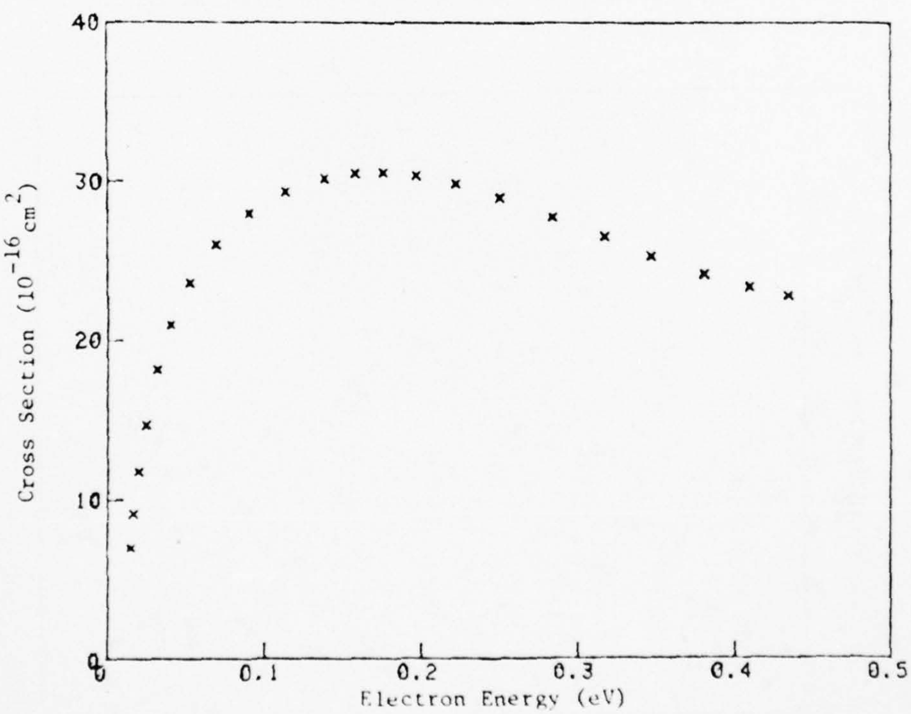
Reference: F. A. Gianturco and N. K. Rahman, J. Phys. B <u>11</u>, 727 (1978)

Tabular and Graphical Data C-1.41c. Rotational excitation cross sections for electrons in HCl (rotational transition is j = 0 to j = 2).

$$e + HCl\ (j = 0) \rightarrow e + HCl\ (j = 2)$$

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
0.015	6.94	0.090	28.0	0.28	27.8
0.016	9.08	0.11	29.4	0.32	26.6
0.019	11.8	0.14	30.2	0.35	25.4
0.024	14.7	0.16	30.5	0.38	24.2
0.032	18.1	0.18	30.6	0.41	23.4
0.040	21.0	0.20	30.4	0.43	22.8
0.052	23.6	0.22	29.9		
0.069	26.1	0.25	29.0		

Cont. Next Column   Cont. Next Column



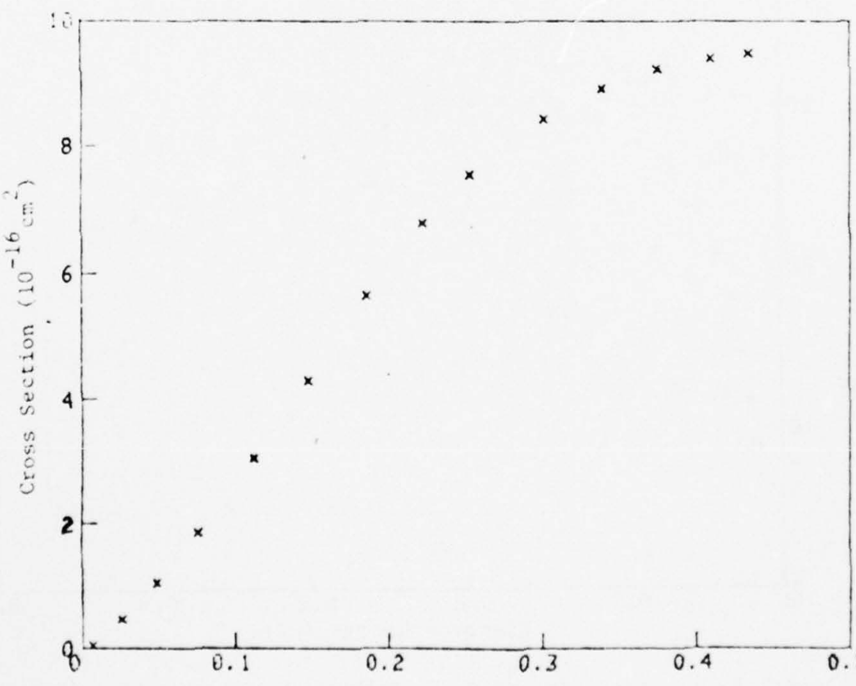
Reference: F. A. Gianturco and N. K. Rahman, J. Phys. B 11, 727 (1978)

Tabular and Graphical Data C-1.41d. Rotational excitation cross sections for electrons in HCl (rotational transition is j = 0 to j = 3).

$$e + HCl\ (j = 0) \rightarrow e + HCl\ (j = 3)$$

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
0.0066	0.0425	0.22	6.81
0.025	0.475	0.25	7.56
0.048	1.06	0.30	8.43
0.076	1.86	0.34	8.94
0.11	3.05	0.38	9.25
0.15	4.31	0.41	9.41
0.18	5.66	0.43	9.49

Cont. Next Column

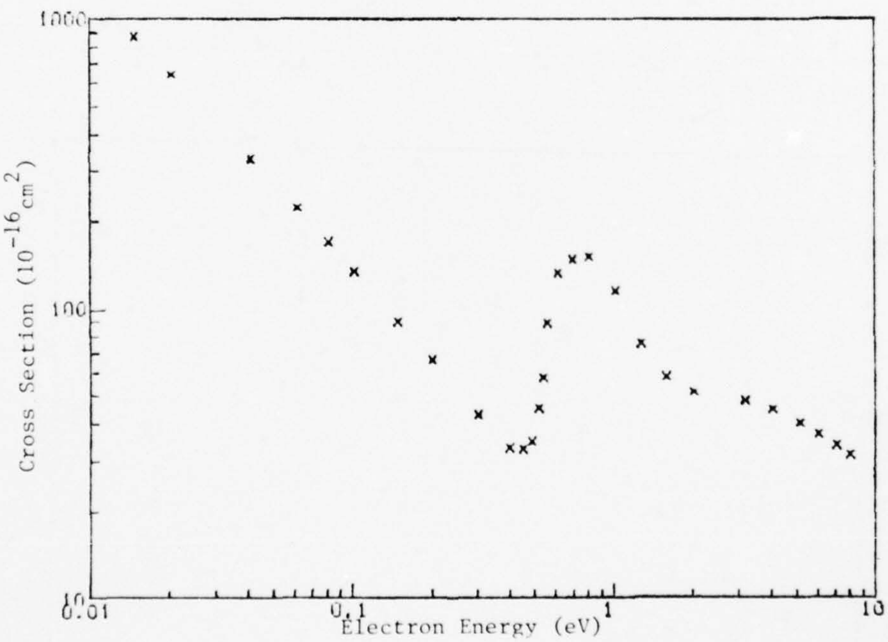


Reference: F. A. Gianturco and N. K. Rahman, J. Phys. B 11, 727 (1978)

Tabular and Graphical Data C-1.42. Preliminary momentum transfer cross sections for electrons in HCl.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0.015	870	0.49	35	3.2	48
0.020	640	0.52	45	4.1	45
0.041	330	0.54	58	5.2	40
0.062	220	0.56	89	6.1	37
0.081	170	0.62	130	7.1	34
0.10	130	0.70	150	8.0	31
0.15	90	0.81	150	10	27
0.20	66	1.0	120	14	22
0.30	43	1.3	76	18	18
0.40	33	1.6	58		
0.45	33	2.0	52		

Cont. Next Column   Cont. Next Column



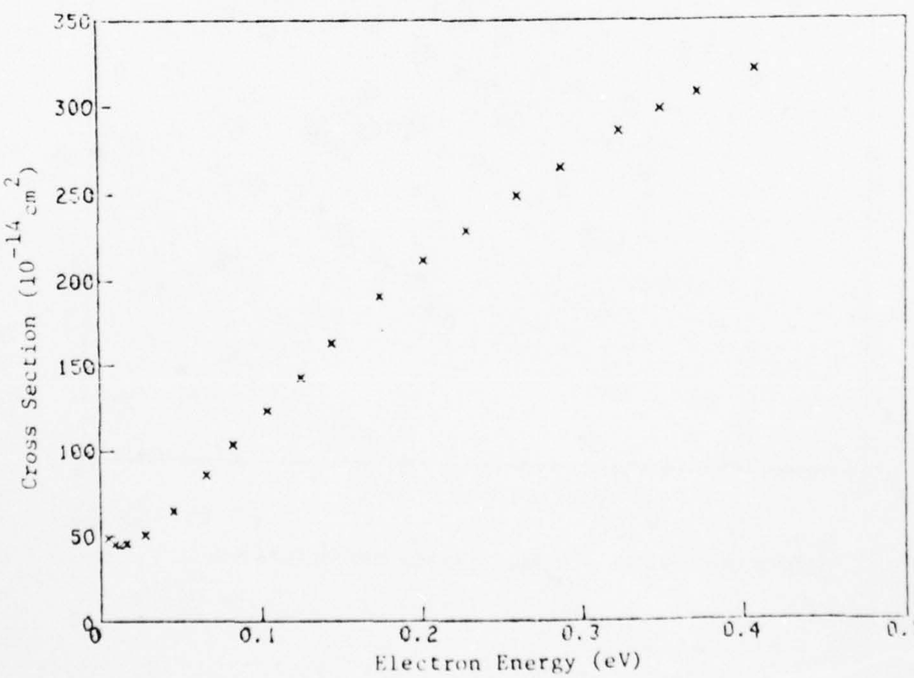
Reference: W. L. Nighan, private communication

Tabular and Graphical Data C-1.43. Elastic scattering cross sections for electrons in HF.

e + HF → e + HF

Electron Energy eV	Cross Section 10^{-14} cm^2	Electron Energy eV	Cross Section 10^{-14} cm^2
0.0046	48.6	0.14	163
0.0090	45.2	0.17	191
0.012	44.5	0.20	212
0.016	45.3	0.23	230
0.027	50.6	0.26	250
0.045	64.8	0.29	266
0.066	85.1	0.32	287
0.083	102	0.35	300
0.10	122	0.37	309
0.13	142	0.41	322

Cont. Next Column



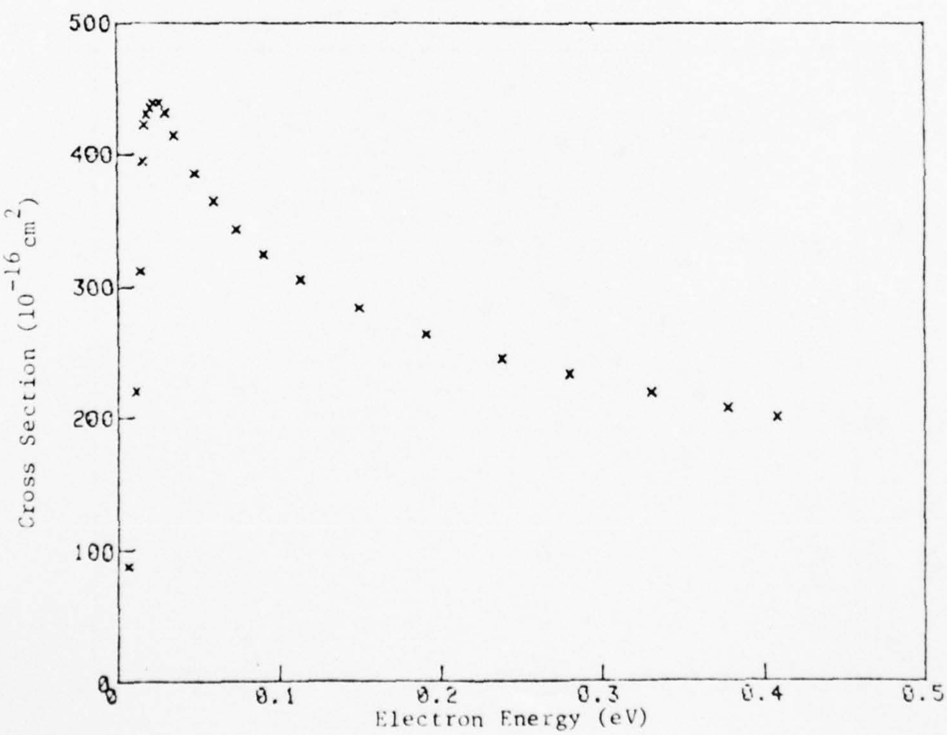
Reference: F. A. Gianturco and N. K. Rahman, J. Phys. B 11, 727 (1978)

Tabular and Graphical Data C-1.44a. Cross sections for rotational excitation of HF by electron impact (rotational transition is j = 0 to j = 1).

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
0.0057	87.6	0.025	439	0.15	285
0.011	220	0.029	432	0.19	264
0.013	313	0.035	414	0.24	245
0.016	395	0.047	386	0.28	234
0.016	422	0.059	366	0.33	220
0.018	431	0.073	344	0.38	207
0.020	436	0.090	325	0.41	201
0.022	439	0.11	306		

Cont. Next Column

Cont. Next Column



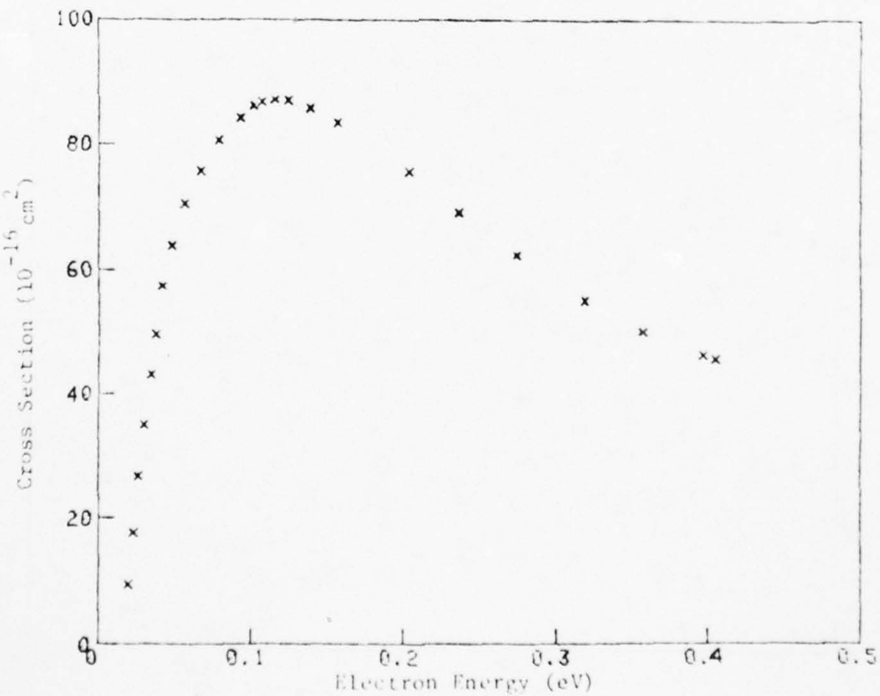
Reference: F. A. Gianturco and N. K. Rahman, J. Phys. B 11, 727 (1978)

Tabular and Graphical Data C-1.44b. Cross sections for rotational excitation of HF by electron impact (rotational transition is j = 0 to j = 2).

$e + HF (j = 0) \rightarrow e + HF (j = 2)$

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
0.019	9.41	0.066	75.7	0.20	75.8
0.023	17.6	0.078	80.6	0.24	69.3
0.026	26.6	0.092	84.2	0.27	62.5
0.029	34.9	0.10	86.1	0.32	55.2
0.034	43.0	0.11	86.7	0.36	50.2
0.037	49.7	0.11	87.1	0.40	46.4
0.041	57.4	0.12	87.0	0.41	45.7
0.047	63.8	0.14	85.8		
0.056	70.5	0.16	83.5		

Cont. Next Column   Cont. Next Column



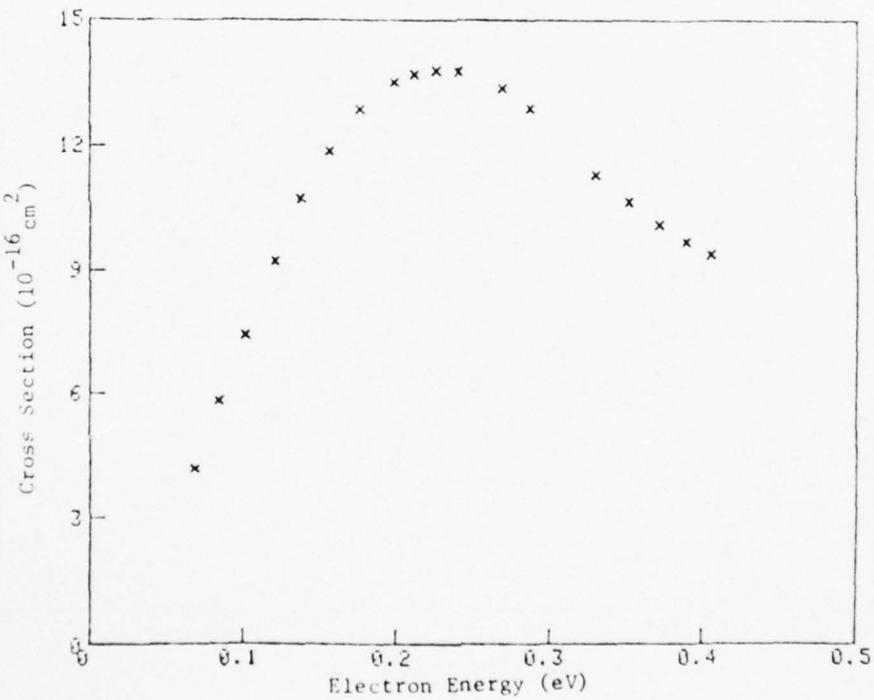
Reference: F. A. Gianturco and N. K. Rahman, J. Phys. B 11, 727 (1978)

Tabular and Graphical Data C-1.44c. Cross sections for rotational excitation of HF by electron impact (rotational transition is j = 0 to j = 3).

$e + HF (j = 0) \rightarrow e + HF (j = 3)$

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
0.068	4.16	0.20	13.5	0.35	10.7
0.084	5.83	0.21	13.7	0.37	10.1
0.10	7.44	0.23	13.8	0.39	9.73
0.12	9.24	0.24	13.8	0.41	9.41
0.14	10.8	0.27	13.4		
0.16	11.9	0.29	12.9		
0.18	12.9	0.33	11.3		

Cont. Next Column   Cont. Next Column

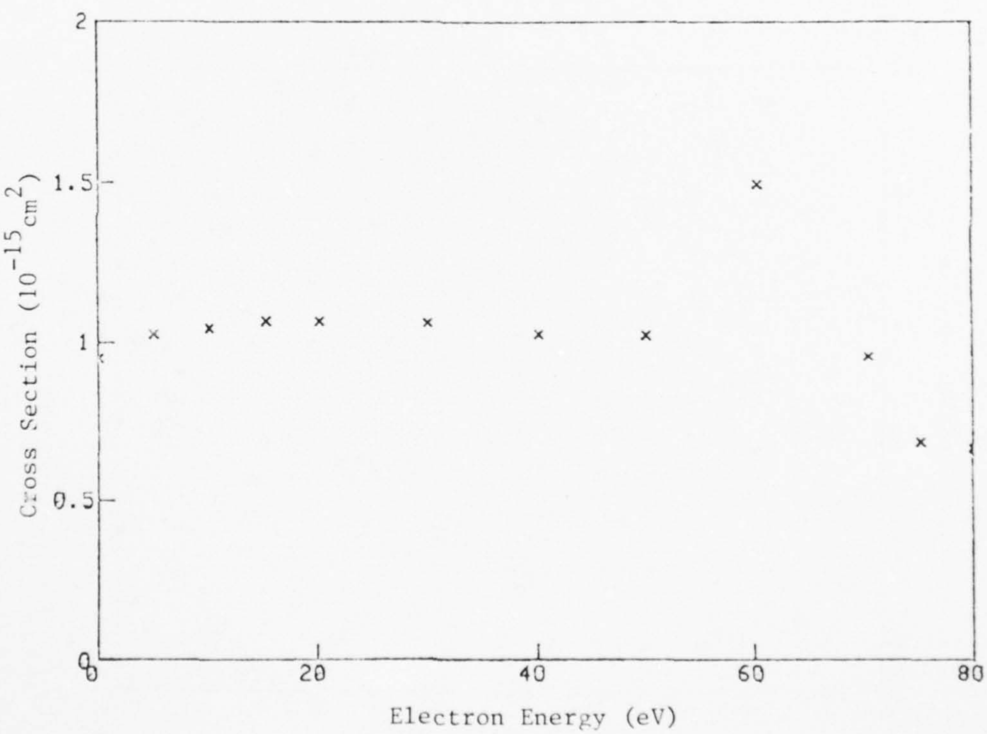


Reference: F. A. Gianturco and N. K. Rahman, J. Phys. B 11, 727 (1978)

Tabular and Graphical Data C-1.45. Momentum transfer cross sections for electrons in SF_6.

Electron Energy eV	Cross Section $10^{-15} cm^2$	Electron Energy eV	Cross Section $10^{-15} cm^2$
0.033	0.948	40	1.03
5.1	1.02	50	1.03
10	1.04	60	1.50
15	1.07	70	0.956
20	1.07	75	0.684
30	1.06	80	0.667

Cont. Next Column

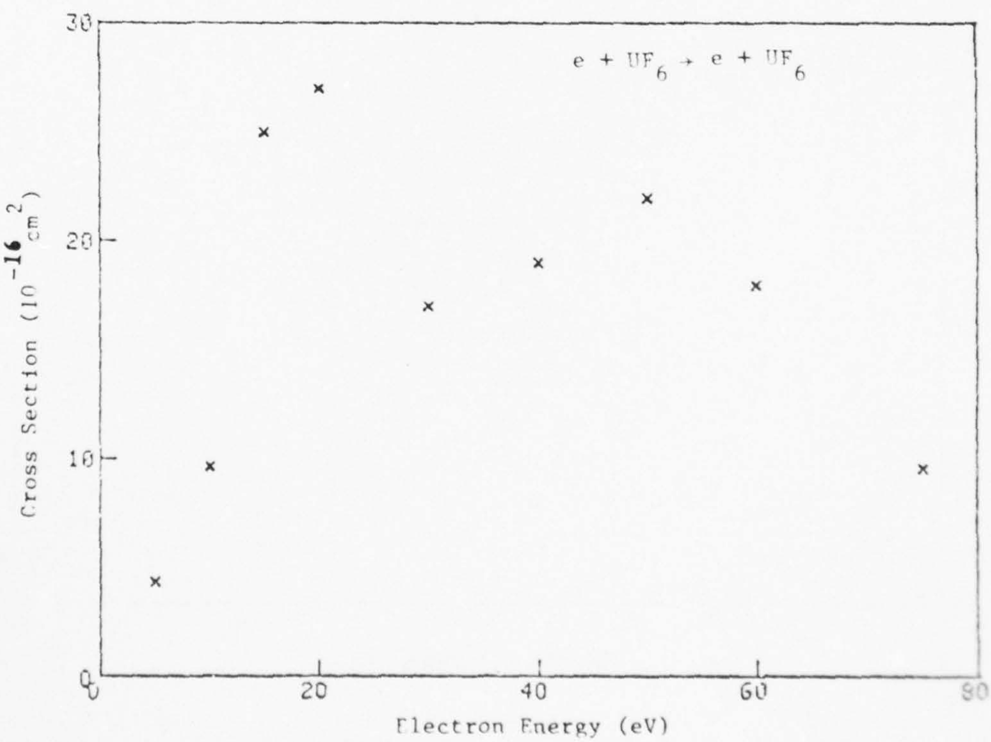


Reference: L. E. Kline, D. K. Davies, C. L. Chen, and P. J. Chantry, (In) Gaseous Dielectrics, L. G. Christophorou, editor, 258 (1978)

Tabular and Graphical Data C-1.46. Elastic scattering cross sections for electrons in UF_6.

$$e + UF_6 \rightarrow e + UF_6$$

Electron Energy eV	Cross Section $10^{-16} cm^2$
5.0	4.3
10.0	9.6
15	25
20	27
30	17
40	19
50	22
60	18
75	9.5

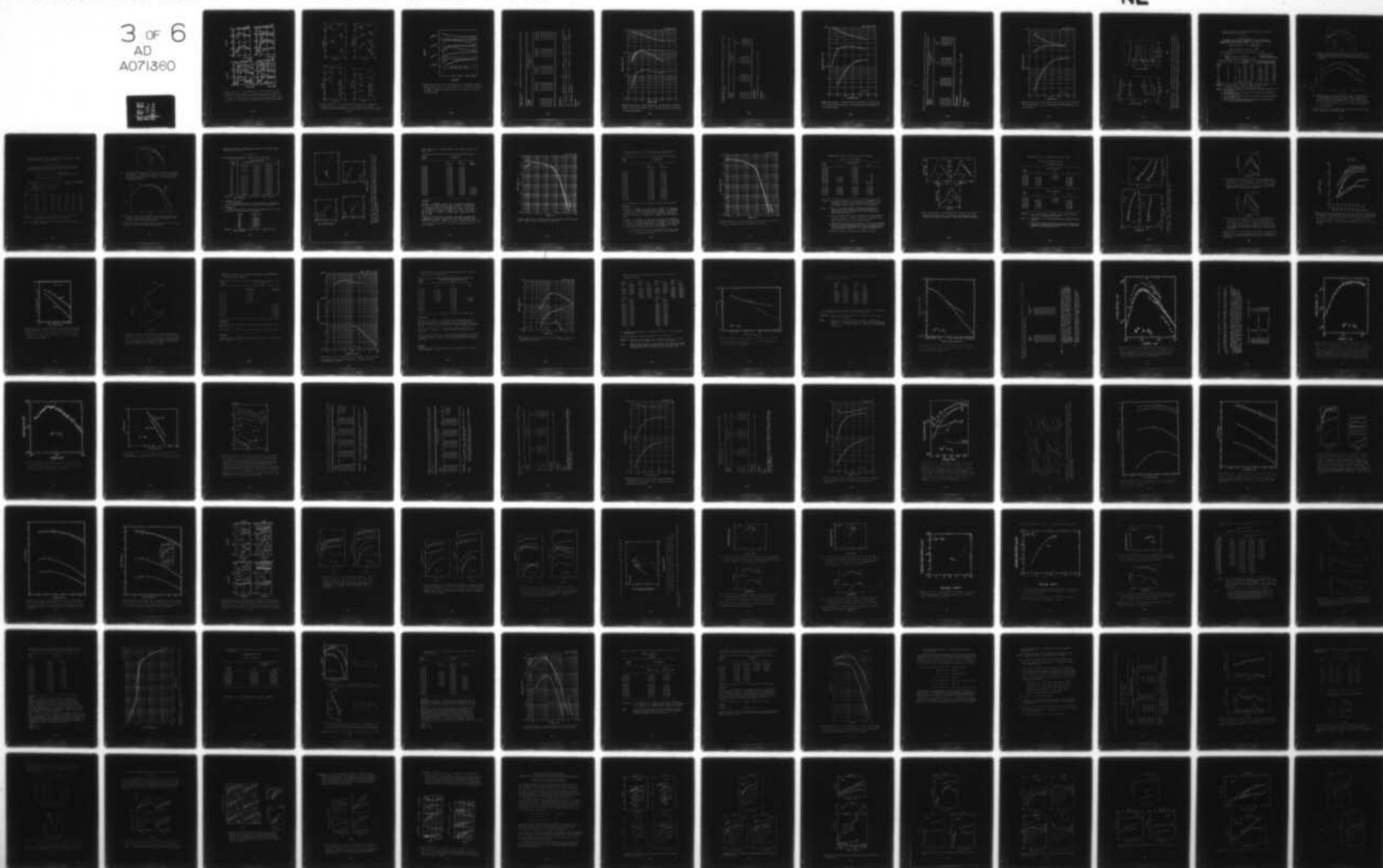


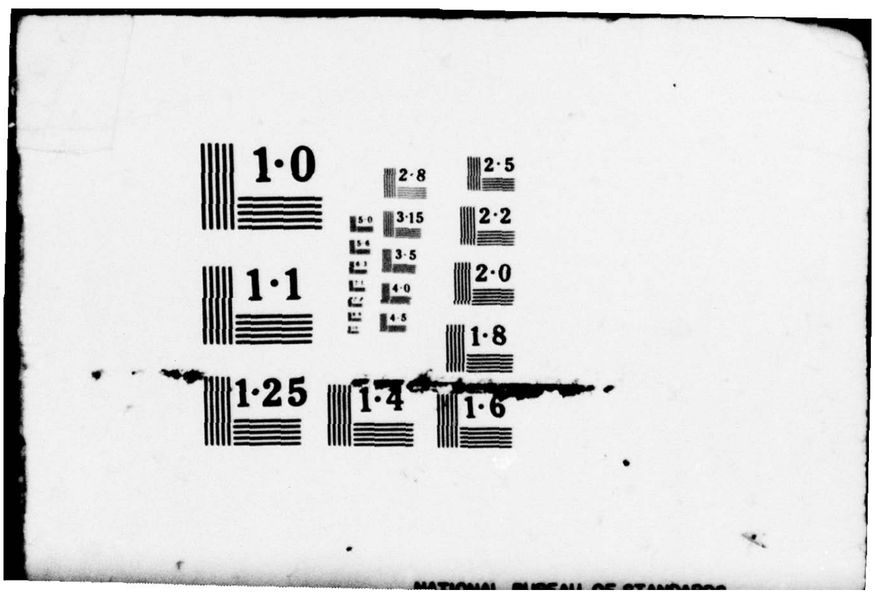
Reference: S. K. Srivastava, S. Trajmar, A. Chutjian and W. Williams, J. Chem. Phys. 64, 2767 (1976)

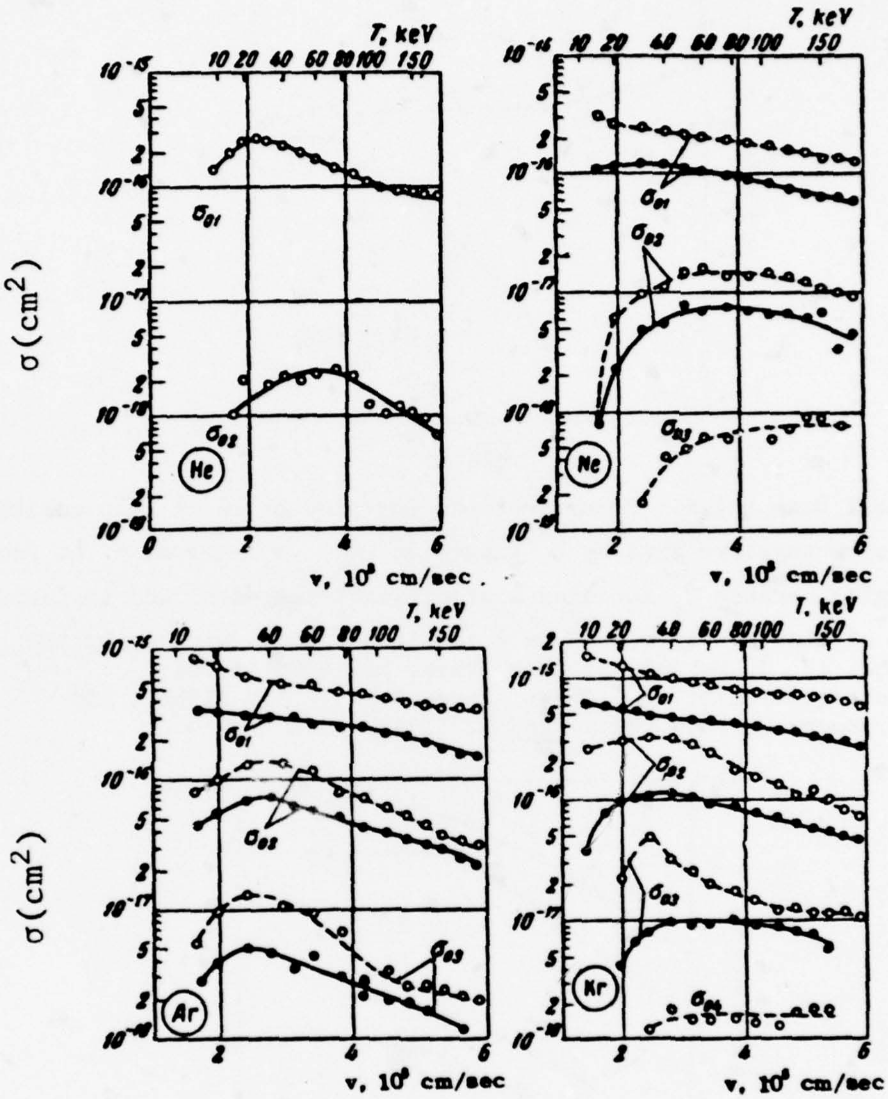
AD-A071 360 ARMY MISSILE RESEARCH AND DEVELOPMENT COMMAND REDSTO--ETC F/G 20/5
COMPILATION OF DATA RELEVANT TO NUCLEAR PUMPED LASERS. VOLUME I--ETC(U)
DEC 78 E W MCDANIEL, M R FLANNERY, E W THOMAS

UNCLASSIFIED DRDMI-H-78-1-VOL-4 NL

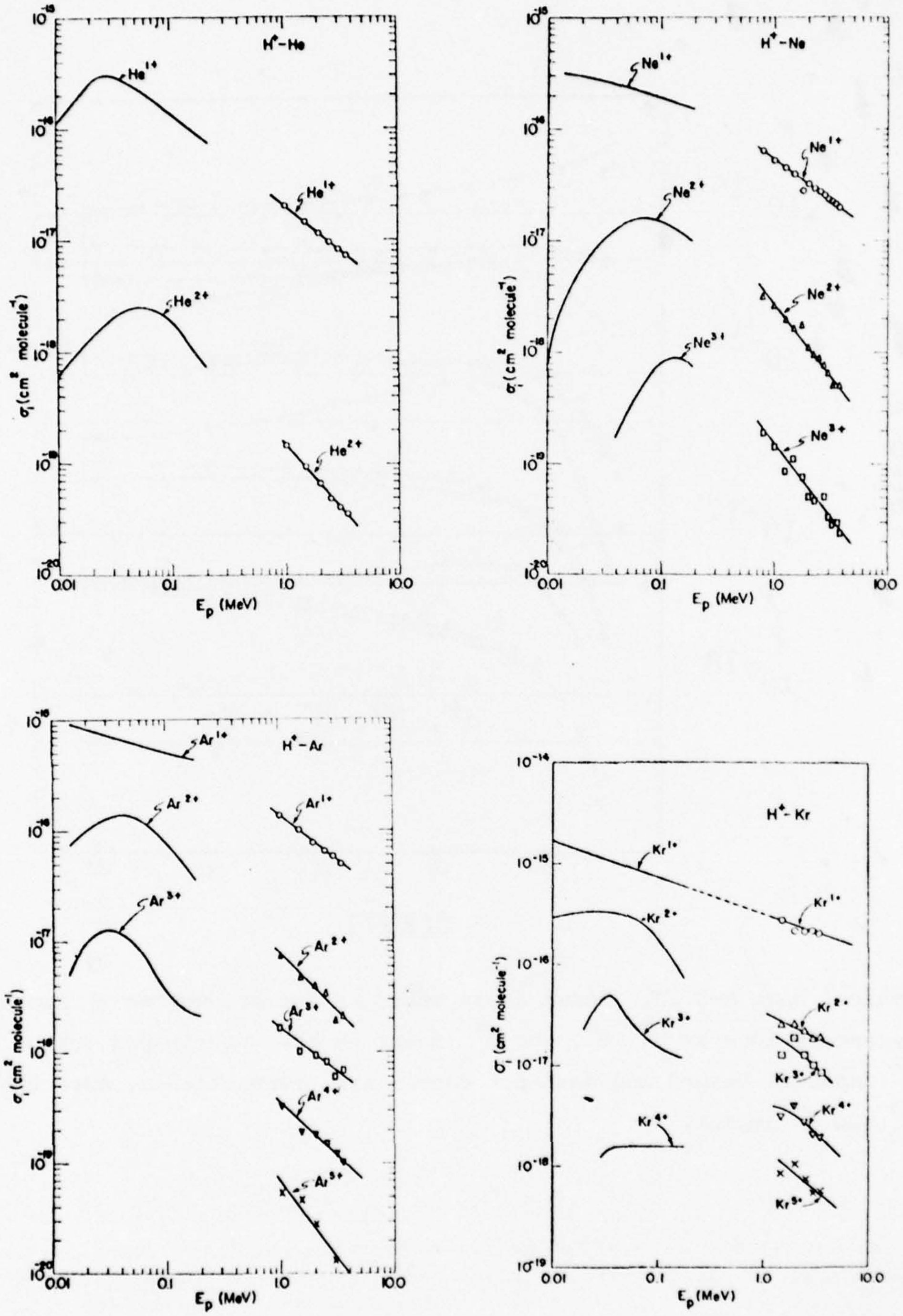
3 OF 6
AD
A071360



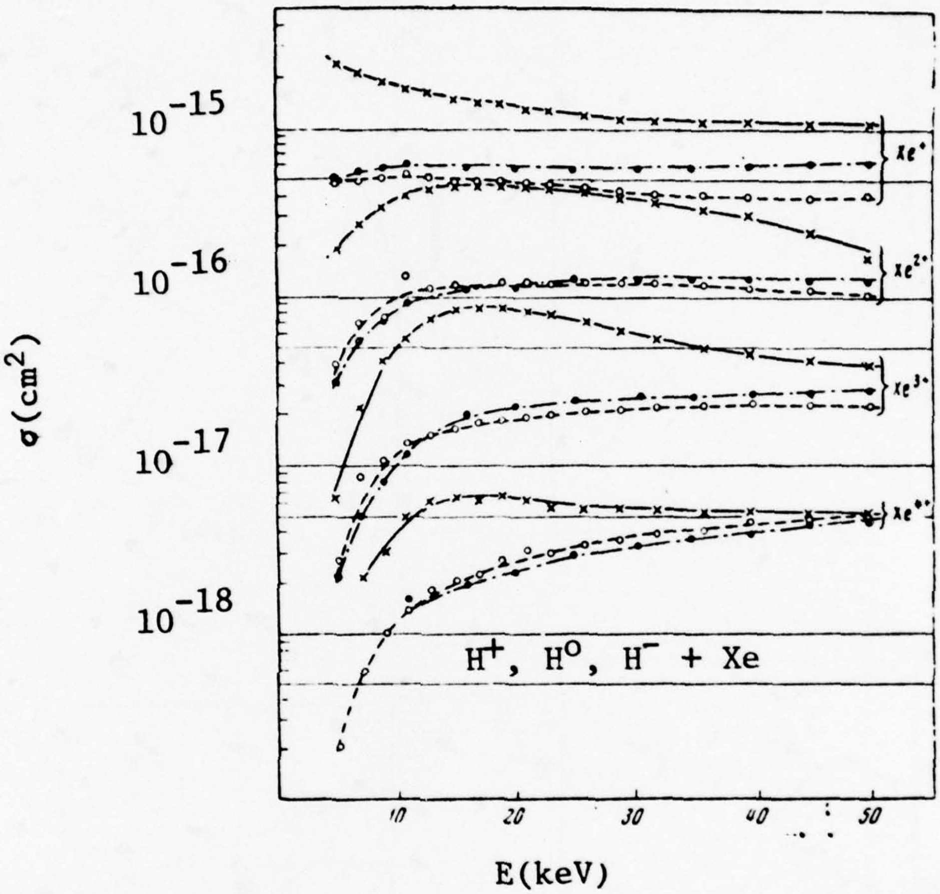

1·0
2·8
2·5
3·15
2·2
3·5
2·0
4·0
4·5
1·1
1·8
1·25
1·4
1·6



Graphical Data B-2.8. Cross sections for forming various slow ions by H^+ (continuous curves) and H^o (broken curves) impact on He, Ne, Ar, and Kr. σ_{oi} is the cross section for removing i electrons from a target atom. Data shown as a function of incident velocity v and energy T. E. L. Solovev et al., Soviet Physics, JETP 15, 459 (1962).



Graphical Data B-2.9. Cross sections for secondary ion production by H^+ impact on He, Ne, Ar, and Kr. E. S. Solovev et al., Soviet Physics, JETP 15, 459 (1962); S. Wexler, J. Chem. Phys. 41, 1714 (1964).



Graphical Data B-2.10. Total cross sections for production of xenon secondary ions by H^+, H^o, and H^- impact on Xe. Continuous curves are H^+ impact. Dashed and dash-dot curves are, respectively, data for H^o and H^- impact.

Tabular Data B-2.11. Cross sections for the production of slow H_2^+ and H^+ from H^+ and H^o impact on H_2.

Energy (keV)	Cross Sections (cm^2)			
	$H^+ + H_2 \rightarrow H_2^+$	$H^+ + H_2 \rightarrow H^+$	$H^o + H_2 \rightarrow H_2^+$	$H^o + H_2 \rightarrow H^+$
5.0 E 00	8.1 E-16	4.0 E-17	4.0 E-17	2.6 E-18
1.0 E 01	8.0 E-16	9.3 E-17	8.2 E-17	1.1 E-17
2.0 E 01	6.2 E-16	1.2 E-16	1.3 E-16	1.7 E-17
3.0 E 01	4.8 E-16	8.7 E-17	1.3 E-16	1.6 E-17
4.0 E 01	3.8 E-16	6.3 E-17	1.2 E-16	1.5 E-17
5.0 E 01	3.4 E-16	4.4 E-17	1.2 E-16	1.2 E-17

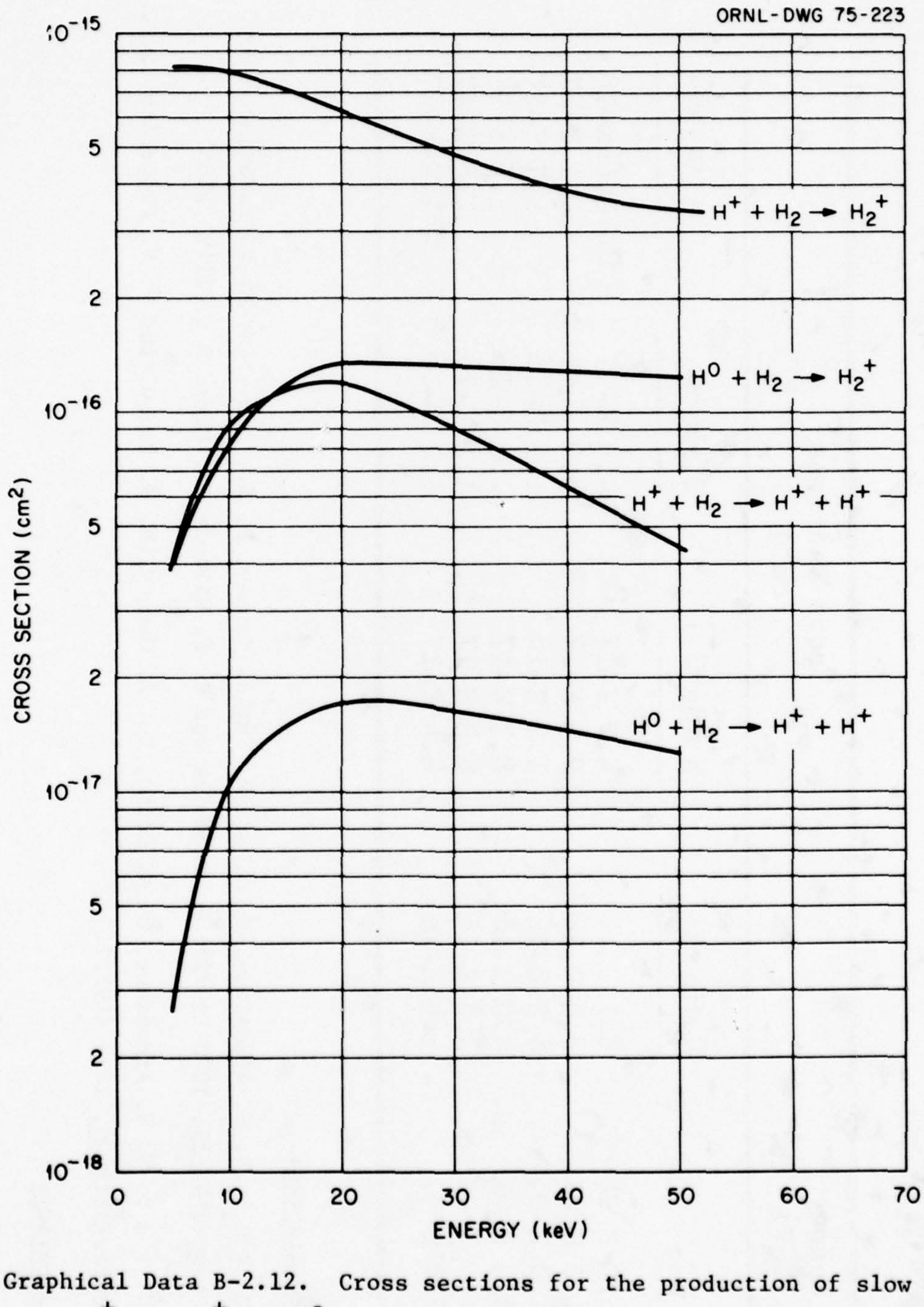
References:

$H^+ + H_2$: V. V. Afrosimov, G. A. Leǐko, Yu. A. Mamaev, M. N. Panov, and N. V. Fedorenko, Sov. Phys.-JETP 35, 1070 (1972); R. Browning and H. B. Gilbody, J. Phys. B 1, 1149 (1968).

$H^o + H_2$: V. V. Afrosimov, G. A. Leǐko, Yu. A. Mamaev, M. N. Panov, and N. V. Fedorenko, Sov. Phys.-JETP 35, 1070 (L972).

Accuracy:

± 20%.



Graphical Data B-2.12. Cross sections for the production of slow H_2^+ and H^+ from H^+ and H^o impact on H_2. (The tabular data are presented on the previous page.)

Tabular Data B-2.13. Cross sections for production of N_2^+, N^+, and N^{2+} ions by protons in N_2 gas.

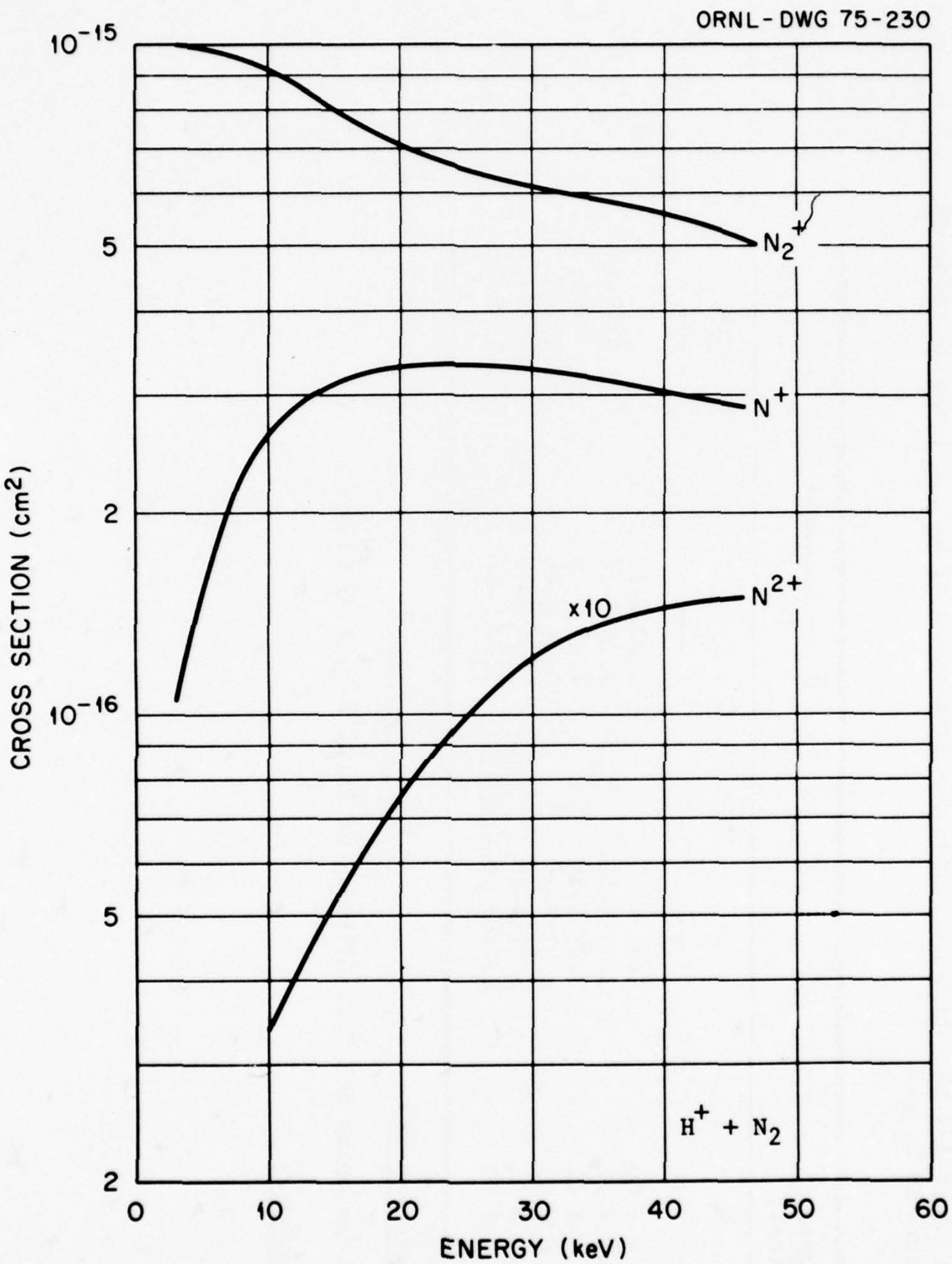
Energy (keV)	Cross Sections (cm^2)		
	N^+	N_2^+	N^{2+}
3.0 E 00	1.05 E-16	1.00 E-15	
1.0 E 01	2.64 E-16	9.20 E-16	3.37 E-18
2.0 E 01	3.23 E-16	7.10 E-16	7.58 E-18
3.0 E 01	3.27 E-16	6.21 E-16	1.23 E-17
4.0 E 01	3.07 E-16	5.60 E-16	1.45 E-17
4.6 E 01	2.86 E-16	5.00 E-16	1.49 E-17

References:

R. Browning and H.B. Gilbody, J. Phys. B 1, 1149 (1968).

Accuracy:

$\pm$ 20%.



Graphical Data B-2.14. Cross sections for production of N_2^+, N^+, and N^{2+} ions by protons in N_2 gas. (The tabular data are presented on the previous page.)

Tabular Data B-2.15. Cross sections for production of O_2^+, O^+, and O^{2+} ions by protons in O_2.

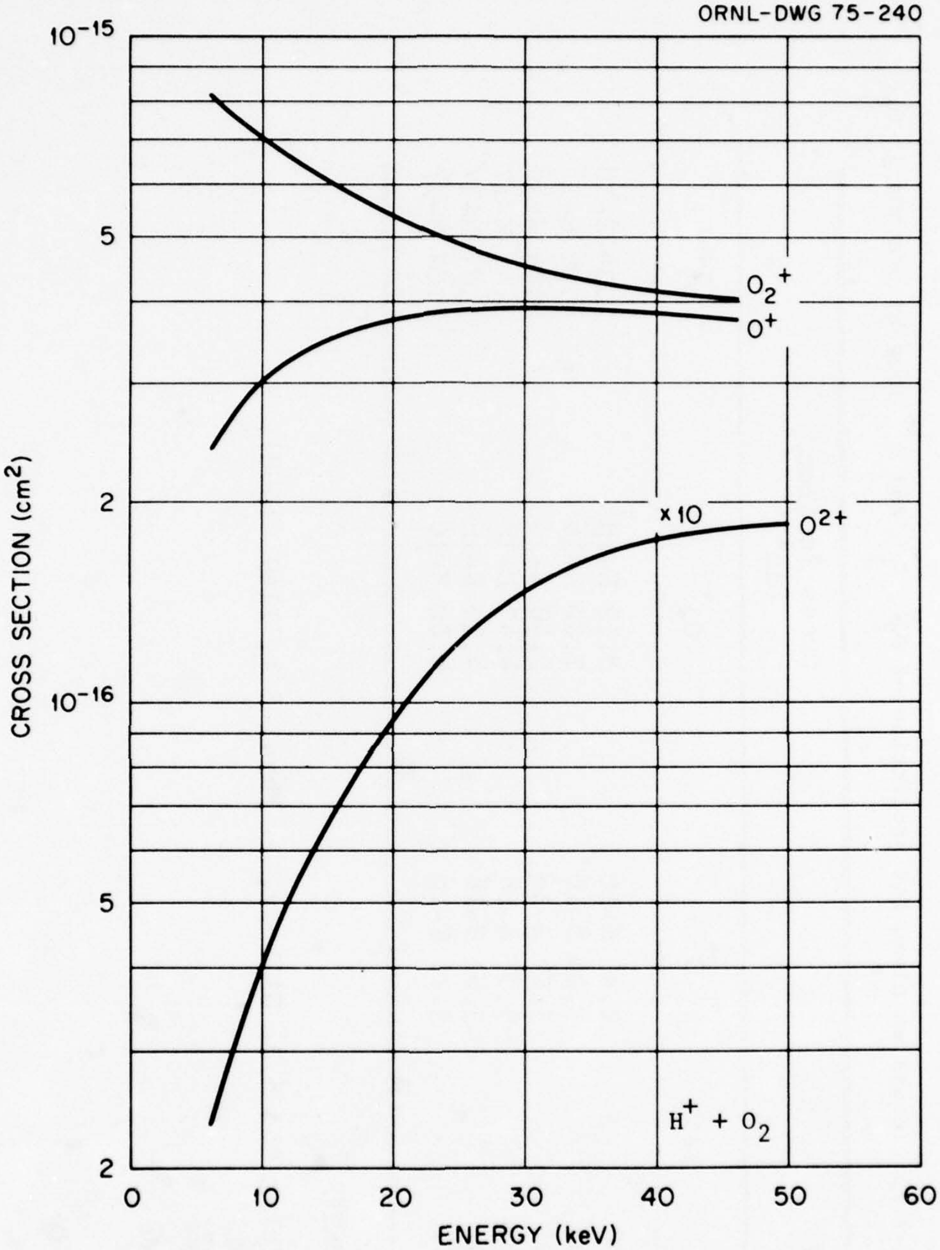
Energy (keV)	Cross Sections (cm^2)		
	O^+	O_2^+	O^{2+}
6.0 E 00	2.40 E-16	8.12 E-16	2.34 E-18
1.0 E 01	3.08 E-16	7.00 E-16	4.26 E-18
2.0 E 01	3.76 E-16	5.40 E-16	9.64 E-18
3.0 E 01	3.87 E-16	4.47 E-16	1.47 E-17
4.0 E 01	3.81 E-16	4.12 E-16	1.77 E-17
4.6 E 01	3.75 E-16	4.00 E-16	1.84 E-17

References:

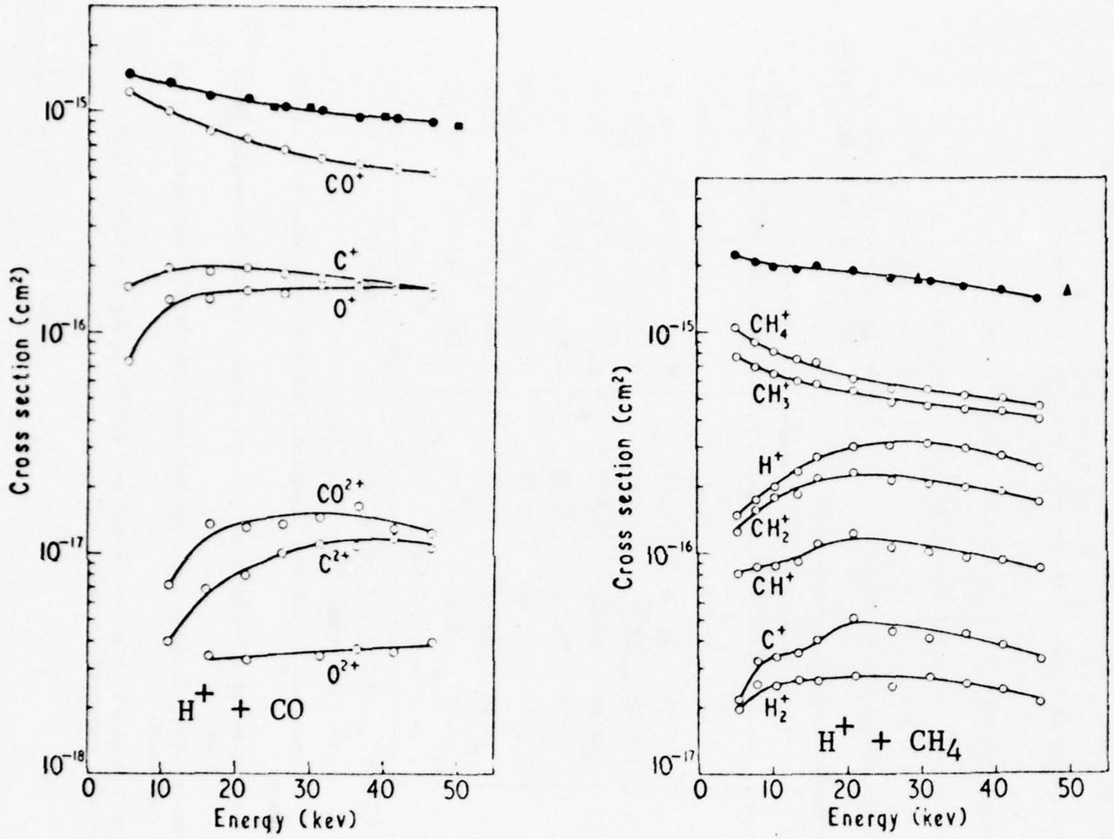
R. Browning and H.B. Gilbody, J. Phys. B 1, 1149 (1968).

Accuracy:

± 20%.



Graphical Data B-2.16. Cross sections for production of O_2^+, O^+, and O^{2+} ions by protons in O_2. (The tabular data were presented on the previous page.)



(a) (b)

Graphical Data B-2.17. Cross sections for formation of various secondary ions in gaseous targets by H^+ impact. (a) CO target; (b) CH_4 target. Open points are cross sections for specific secondary ions; the closed points are the total cross sections for formation of all positive ions. R. Browning and H. B. Gilbody, J. Phys. B 1, 1149 (1968).

Tabular Data B-2.18. Stripping Cross Sections of H atoms in He, Ne, Ar, Kr, Xe, H_2, N_2.

$$H + X \rightarrow H^+ + X + e$$

We suggest use of the following semi-empirical analytic expression by Green and McNeal which adequately represents the available data; applicable parameters are shown in tabular form below.

General analytic form $$\sigma(E) = \frac{\sigma_o (Za)^{\Omega} (E-I)^{\nu}}{J^{\Omega+\nu} + E^{\Omega+\nu}} \quad (1)$$

High energy asymptotic form $\sigma(E) = \sigma_o \left(\frac{Za}{E}\right)^{\Omega}$

$\sigma(E)$ = Cross section in cm^2 at impact energy E(keV)

σ_o = 10^{-16} cm^2

Z = Number of electrons in one molecule of gas.

I = Ionization threshold of hydrogen (0.0135 keV).

$\Omega = 0.75$ (a)

ν = See table below (b)

a,J = Parameters obtained by fitting to data. See below.

Target Characteristics		Three Parameters (ν, J and a) Varied (c)			Two Parameters (J and a) Varied (ν fixed = 0.666) (c)		
Target Species	Z	ν	J (keV)	a (keV)	ν	J (keV)	a (keV)
He	2	0.56	21.00	46.40	0.666	21.00	46.40
Ne	10	0.60	60.63	42.93	0.666	51.26	37.27
Ar	18	0.69	88.90	91.00	0.666	89.90	91.00
Kr	36	0.79	98.00	78.00	0.666	98.00	78.00
Xe	54	0.76	59.40	33.20	0.666	59.39	33.20
H_2	2	0.68	38.85	79.50	0.666	39.54	80.00
N_2	14	0.59	56.50	94.92	0.666	49.64	88.22
Others		(See note (d) below)					

__Reference__ A. E. S. Green and R. J. McNeal, J. Geophys. Res. 76, 133 (1971).

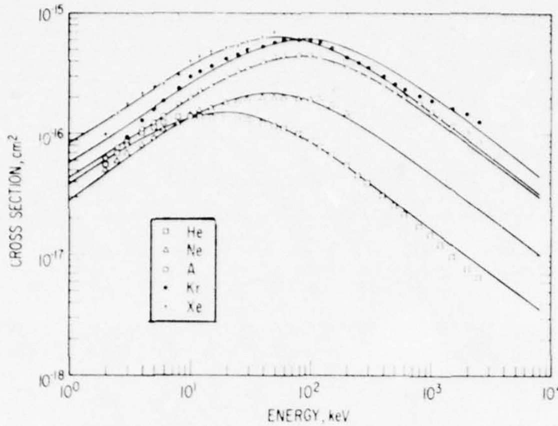
H. Tawara and A. Russek, Rev. Mod. Phys. 45, 178 (1973).

__Notes__ (a) This value of Ω is consistent with the asymptotic high energy behaviour of the Born Approximation.

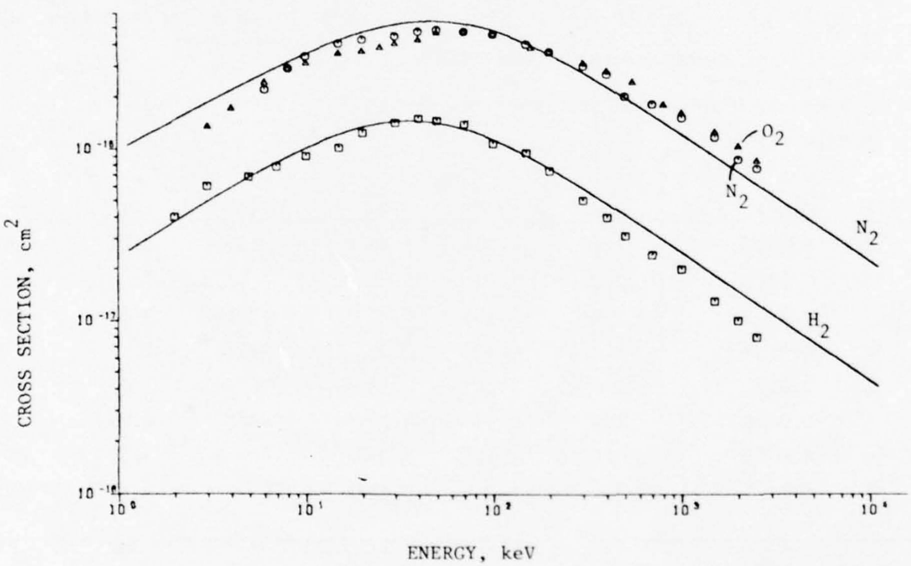
(b) This parameter is taken as 0.666 for the two parameter fit and is varied in the three parameter fit.

(c) The three parameter form is most accurate but does not differ appreciably from the two parameter form.

(d) For other gases a reasonable estimate may be made by using average values of ν, J and a with appropriate values of Z.



(a) Stripping cross sections for hydrogen atoms in rare gases. The curves show the fits obtained with Equation 1 with Ω = 0.75, ν = 0.666, and variable a and J. The data were taken from Green and McNeal.



(b) Stripping cross sections for hydrogen atoms in molecular gases. The curves show the fits with Ω = 0.75, and ν = 0.666. The data were taken from Tawara and Russek. Green and McNeal do not present an analytic expression for O_2, but clearly the data for O_2 lie close to those for N_2 and can be well represented by the same expression.

Graphical Data B-2.19. Stripping cross sections for hydrogen atoms in (a) rare gases and (b) molecular gases.

Tabular Data B-2.20. Electron capture cross sections for protons in He, Ne, Ar, Kr, Xe, H_2, N_2, and O_2.

$$H^+ + X \rightarrow H + X^+$$

We suggest use of the following semi-empirical analytic expression by Green and McNeal which adequately represents the available data; applicable parameters are shown in tabular form below.

General analytic form $$\sigma(E) = \sigma_o \frac{(Za)^{\Omega} \quad (E-I)^{\nu}}{J^{\Omega+\nu} + E^{\Omega+\nu} + (Za)^{\Omega} E^{\nu} (E/C)^{\Lambda}}$$

High energy asymptotic form $$\sigma(E) = (\frac{C}{E})^{\Lambda}$$

$\sigma(E)$ = Cross section in cm^2 at impact energy E(keV)

σ_o = 10^{-16} cm^2

Z = Number of electrons in one molecule of target gas

I = Ionization threshold of target gas (keV)

ν, J, Ω, a, Λ, C = parameter obtained by fitting to data. See Below.

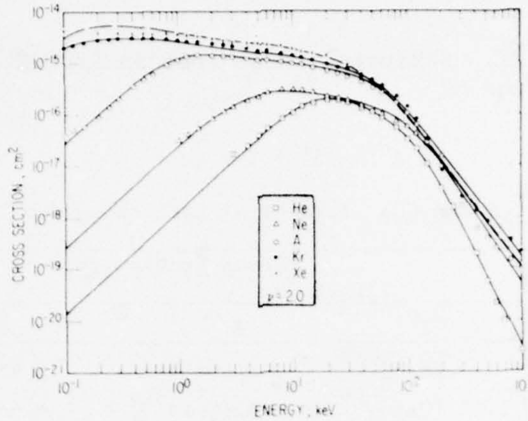
Target Characteristics

Species	Z	$I^{(a)}$ (keV)	ν	J	Ω	a	Λ	C
He	2	0.0247	2.0	16.86	1.08	28.95	4.50	100.
Ne	10	0.0215	2.0	5.216	0.71	5.57	4.00	173.
Ar	18	0.0157	2.0	0.894	0.35	316.56	3.38	106.
Kr	36	0.0139	2.0	0.130	0.30	1364.67	2.86	110.
Xe	54	0.0121	2.0	0.141	0.38	347.67	3.00	100.
H_2	2	0.0156	2.0	1.215	0.271	4084.	4.80	75.8
N_2	14	0.0155	2.0	1.433	0.375	258.	3.30	108.
O_2	16	0.0125	2.0	0.057	0.258	1038.	3.50	125.

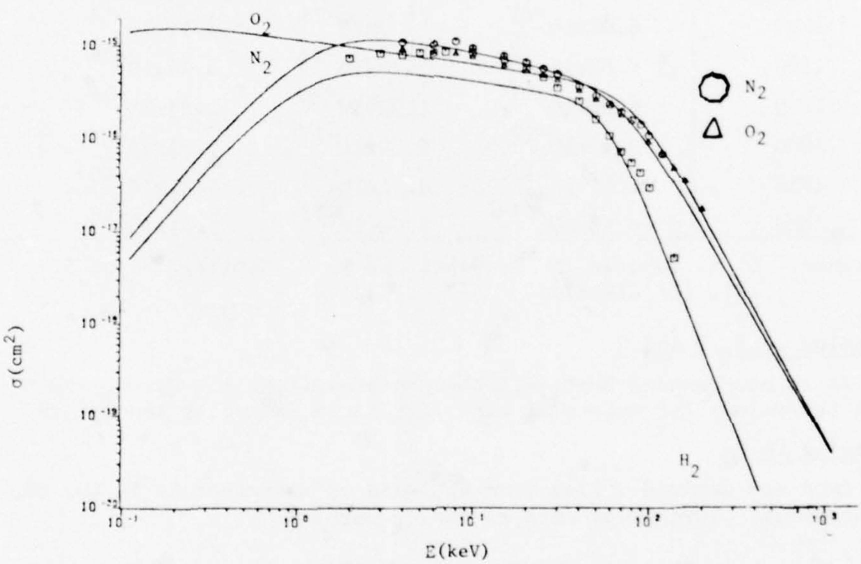
References A. E. S. Green and R. J. McNeal, J. Geophys. Res. 76, 133 (1971).

H. Tawara and A. Russek, Rev. Mod. Phys. 45, 178 (1973).

Notes (a) "Handbook of Chemistry and Physics" 46th Edition (Chemical Rubber Pub. Co., Cleveland, 1966).



(a) Electron capture cross sections for fast protons in rare gases. The value of ν in Equation 2 is fixed at 2.0; other parameters were adjusted. The curves are plots of Equation 1 with the parameters listed in the facing table. The data were taken from Green and McNeal.



(b) Electron capture cross sections for protons in molecular gases. Details of curves are the same as those in caption (a). The data were taken from Tawara and Russek.

Graphical Data B-2.21. Electron capture cross sections for fast protons in (a) rare gases and (b) molecular gases.

Tabular Data B-2.22. Stripping cross sections for H atoms in H_2O, CO, CO_2, C, O, and N.

$$H + X \rightarrow H^+ + X + e.$$

(a) Stripping in H_2O, CO and CO_2 (Graphical Data on Facing Page)

Energy (keV)	Cross Section cm^2 Target Gas		
	H_2O	CO	CO_2
100	3.18×10^{-16}	4.60×10^{-16}	5.85×10^{-16}
200	2.70×10^{-16}	3.60×10^{-16}	4.69×10^{-16}
300	2.10×10^{-16}	3.25×10^{-16}	4.28×10^{-16}
400		2.63×10^{-16}	3.72×10^{-16}
550	1.45×10^{-16}	2.32×10^{-16}	3.27×10^{-16}
800	1.12×10^{-16}	1.63×10^{-16}	2.44×10^{-16}
1000	9.81×10^{-17}	1.47×10^{-16}	2.17×10^{-16}
1250	8.02×10^{-17}	1.27×10^{-16}	1.91×10^{-16}
1500	6.82×10^{-17}	1.10×10^{-16}	1.69×10^{-16}
1750	6.07×10^{-17}	1.02×10^{-16}	1.51×10^{-16}
2000	5.67×10^{-17}	9.10×10^{-17}	1.33×10^{-16}
2250	5.11×10^{-17}	8.51×10^{-17}	1.22×10^{-16}
2500	4.91×10^{-17}	7.94×10^{-17}	1.11×10^{-16}

Reference: L. H. Toburen, M. Y. Nakai and R. A. Langley, Phys. Rev. 171, 114 (1968).

(b) Stripping in H, O and N

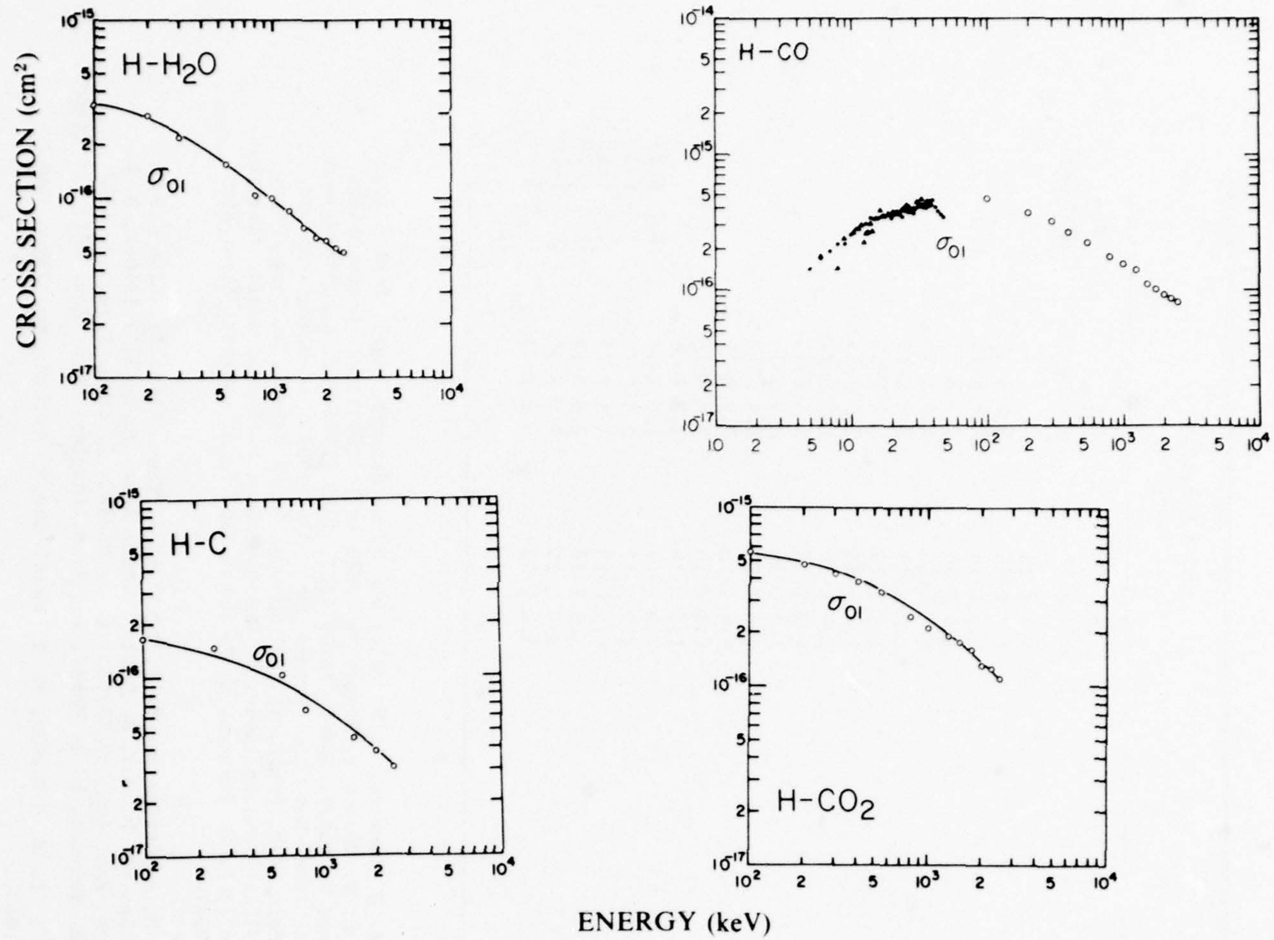
It is recommended that half the cross sections for H_2, N_2 and O_2 be used; the values for molecular cases are shown in B-2.18 and B-2.19.

(c) Stripping in C

Data are derived values from analysis of measurements in CO, CO_2 and hydrocarbons. (Graphical data on facing page).

Energy (keV)	Cross Section cm^2
100	1.87×10^{-16}
300	1.36×10^{-16}
550	1.01×10^{-16}
800	0.64×10^{-16}
1500	0.45×10^{-16}
2000	0.37×10^{-16}
2500	0.32×10^{-16}

Reference: L. H. Toburen, M. K. Nakai and R. A. Langley, Phys. Rev. 171, 114 (1968).



Graphical Data B-2.23. Stripping cross sections for H atoms in H_2O, CO, CO_2, and C. The data were reproduced from the compendium by Dehmel et al., Atomic Data 5, 231 (1973). Data for energies above 100 keV were taken from Toburen et al., and are reproduced on page 1552.

Tabular Data B-2.24. Electron capture cross sections for H^+ in CO, CO_2, and C.

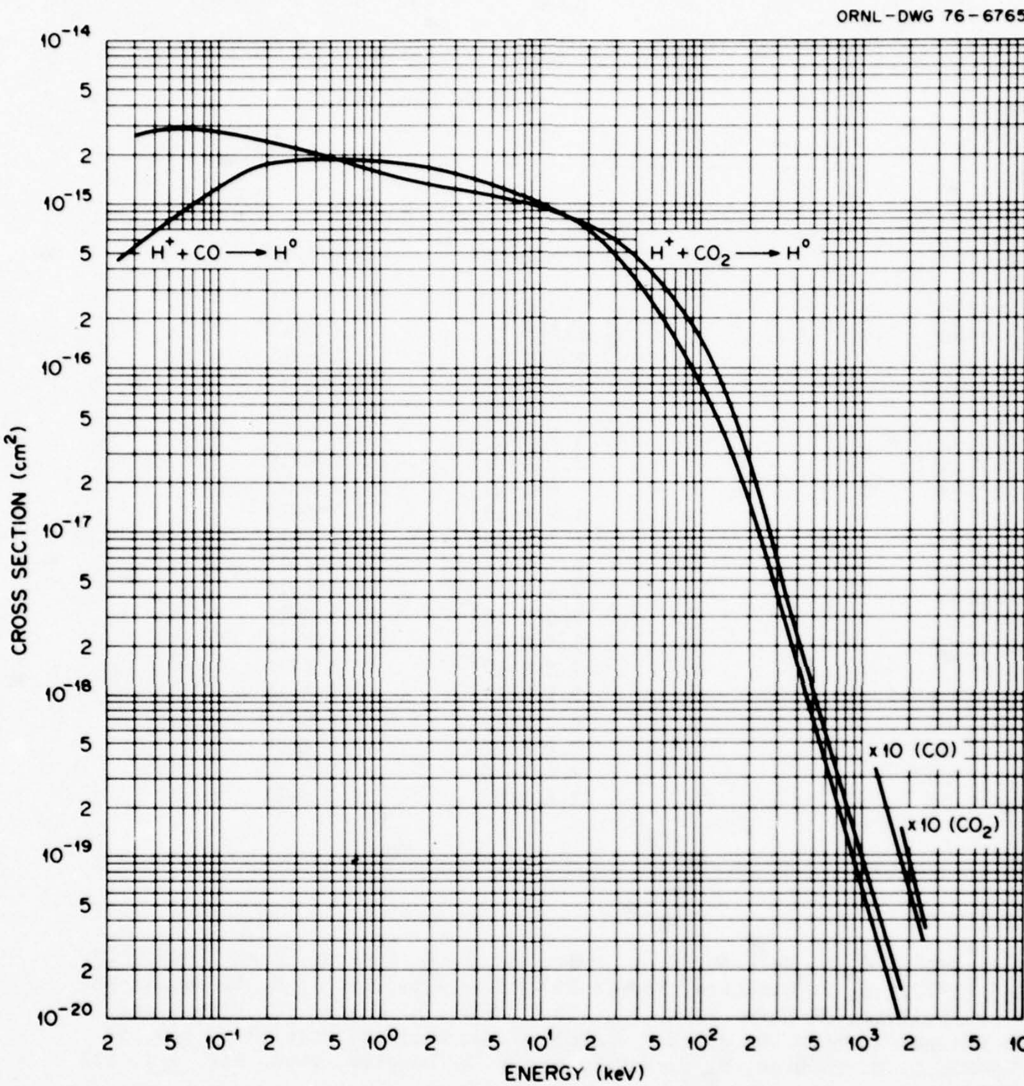
Energy (keV)	Cross Sections (cm^2)		
	σ_{10} $H^+ + CO \rightarrow H^\circ$	σ_{10} $H^+ + CO_2 \rightarrow H^\circ$	σ_{10} $H^+ + C \rightarrow H^o$
2.5 E-02	4.7 E-16		
5.0 E-02	7.7 E-16	2.9 E-15	
7.5 E-02	1.0 E-15	2.8 E-15	
1.0 E-01	1.3 E-15	2.7 E-15	
2.0 E-01	1.7 E-15	2.4 E-15	
5.0 E-01	1.9 E-15	1.9 E-15	
7.5 E-01	1.8 E-15	1.7 E-15	
1.0 E 00	1.8 E-15	1.5 E-15	
2.0 E 00	1.7 E-15	1.3 E-15	
5.0 E 00	1.3 E-15	1.1 E-15	
7.5 E 00	1.1 E-15	1.0 E-15	
1.0 E 01	1.0 E-15	9.4 E-16	
2.0 E 01	6.8 E-16	7.5 E-16	
5.0 E 01	2.5 E-16	3.8 E-16	
7.5 E 01	1.3 E-16	2.3 E-16	
1.0 E 02	7.9 E-17	1.6 E-16	4.5 E-17
2.0 E 02	1.5 E-17	2.5 E-17	1.3 E-18
5.0 E 02	6.5 E-19	1.1 E-18	1.9 E-19
7.5 E 02	1.8 E-19	2.6 E-19	6.3 E-20
1.0 E 03	6.7 E-20	9.0 E-20	2.6 E-20
2.5 E 03	3.0 E-21	3.6 E-21	1.1 E-21

References:

$H^+ + CO \rightarrow H^\circ$: K. H. Berkner, R. V. Pyle, and J. W. Stearns, Nucl. Fusion 10, 145 (1970); E. S. Chambers, Report No. UCRL-14214 (1965); J. Desesquelles, G. D. Cao, and M. Dufay, Compt. Rend. 262B, 1329 (1966); H. B. Gilbody and J. B. Hasted, Proc. Roy. Soc. London 238A, 334 (1956); E. Gustafsson and and E. Lindholm, Ark. Fysik, 18, 219 (1960); R. J. McNeal, J. Chem. Phys. 53, 4308 (1970); M. C. Poulizac, J. Desesquelles, M. Dufay, Annls. Astrophys. 30, 301 (1967); L. H. Toburen, M. Y. Nakai, and R. A. Langley, Phys. Rev. 171, 114 (1968).

$H^+ + CO_2 \rightarrow H^\circ$: M. A. Coplan and K. W. Ogilvie, J. Chem. Phys. 52, 4154 (1970); J. Desesquelles, G. D. Cao, M. Dufay, Compt. Rend. 262B, 1329 (1966); D. W. Koopman, Phys. Rev. 166, 57 (1968); R. J. McNeal, J. Chem. Phys. 53, 4308 (1970); L. H. Toburen, M. Y. Nakai, and R. A. Langley, Phys. Rev. 171, 114 (1968).

$H^+ + C \rightarrow H^o$: L. H. Toburen, M. Y. Wakai and R. A. Langley, Phys. Rev. 171, 114 (1968).



Graphical Data B-2.25. Electron capture cross section for H^+ in CO and CO_2. (Tabular data are presented on page 1554).

Tabular Data B-2.26. Electron capture cross sections for H^+ in H_2O, CH_4, H, N, and O. (For H, N and O, see note.)

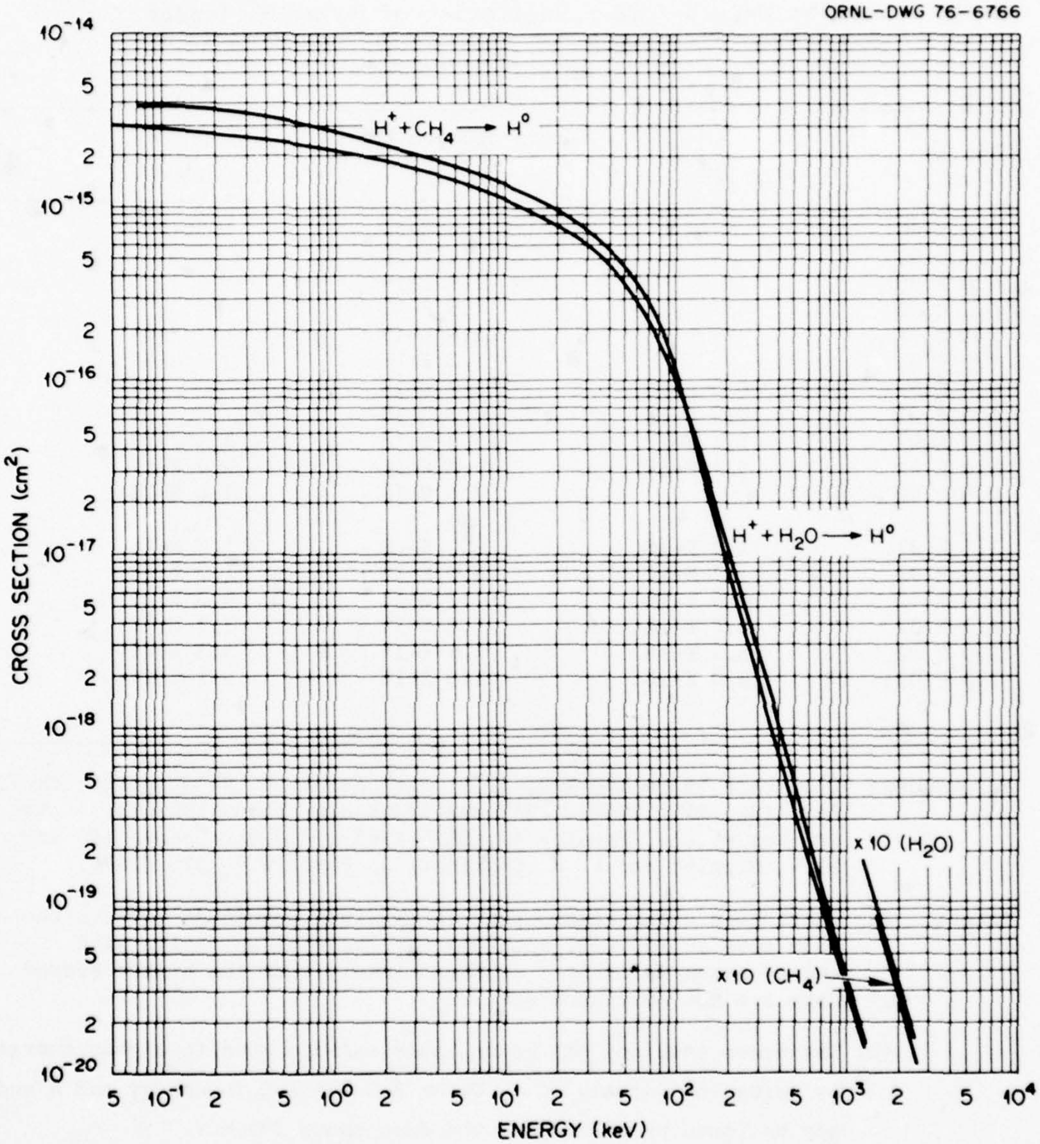
Energy (keV)	Cross Sections (cm^2)	
	σ_{10} $H^+ + H_2O \rightarrow H°$	σ_{10} $H^+ + CH_4 \rightarrow H°$
5.0 E-02	3.0 E-15	
7.0 E-02	2.9 E-15	3.8 E-15
1.0 E-01	2.8 E-15	3.8 E-15
2.0 E-01	2.6 E-15	3.6 E-15
5.0 E-01	2.3 E-15	3.1 E-15
7.5 E-01	2.2 E-15	2.8 E-15
1.0 E 00	2.1 E-15	2.7 E-15
2.0 E 00	1.8 E-15	2.2 E-15
5.0 E 00	1.4 E-15	1.7 E-15
7.5 E 00	1.2 E-15	1.5 E-15
1.0 E 01	1.1 E-15	1.3 E-15
2.0 E 01	7.6 E-16	9.3 E-16
5.0 E 01	3.5 E-16	4.5 E-16
7.5 E 01	1.8 E-16	2.4 E-16
1.0 E 02	9.0 E-17	1.0 E-16
2.0 E 02	1.1 E-17	8.0 E-18
5.0 E 02	4.3 E-19	2.9 E-19
7.5 E 02	9.2 E-20	7.4 E-20
1.0 E 03	3.4 E-20	3.0 E-20
2.5 E 03	1.6 E-21	1.1 E-21

References:

$H^+ + H_2O \rightarrow H°$: K. H. Berkner, R. V. Pyle, and J. W. Stearns, Nucl. Fusion 10, 145 (1970); E. S. Chambers, Report No. UCRL-14214 (1965); M. A. Coplan and K. W. Ogilvie, J. Chem. Phys. 52, 4154 (1970); R. Dagnac, D. Blanc, and D. Molina, J. Phys. B. 3, 1239 (1970); D. W. Koopman, Phys. Rev. 166, 57 (1968); L. H. Toburen, M. Y. Nakai, and R. A. Langley, Phys. Rev. 171, 114 (1968).

$H^+ + CH_4 \rightarrow H°$: K. H. Berkner, R. V. Pyle, and J. W. Stearns, Nucl. Fusion 10, 145 (1970); E. S. Chambers, Report No. UCRL-14214 (1965); J. G. Collins and P. Kerbarle, J. Chem. Phys. 46, 1087 (1967); J. Desesquelles, G. D. Cao, and M. Dufay, Compt. Rend. 262B, 1329 (1966); D. W. Koopman, J. Chem. Phys. 49, 5203 (1968); R. J. McNeal, J. Chem. Phys. 53, 4308 (1970); L. H. Toburen, M. Y. Nakai, and R. A. Langley, Phys. Rev. 171, 114 (1968).

Note: For capture in H, N and O it is recommended that half the cross sections for H_2, N_2 and O_2 be used; the data for the molecular cases are shown in B-2.20 and B-2.21.



Graphical Data B-2.27. Electron capture cross sections for H^+ in H_2O and CH_4. (Tabular data are presented on page 1556).

Tabular Data B-2.28. Excitation of He by H^+ impact.

$$H^+ + He \rightarrow H^+ + He\ (n^1P)$$

Energy keV	Cross Section cm^2 2^1P	3^1P	4^1P
2.0 E 00		7.6 E-21	
4.0 E 00		5.1 E-20	
6.0 E 00		1.0 E-19	
8.0 E 00		2.5 E-19	
1.0 E 01		5.6 E-19	1.[illegible]-19
2.0 E 01		1.2 E-18	3.[illegible]-19
4.0 E 01	6.0 E-18	1.7 E-18	[illegible]19
6.0 E 01	7.5 E-18	7.8 E-18	[illegible]9
8.0 E 01	1.1 E-17	3.4 E-18	9.[illegible]19
1.0 E 02	1.4 E-17	3.8 E-18	9.5 E-19
2.5 E 02		3.9 E-18	1.0 E-18
1.5 E 02	1.3 E-17	3.2 E-18	1.3 E-18
2.0 E 02	1.2 E-17	3.0 E-18	1.2 E-18
4.0 E 02	8.6 E-18	2.2 E-18	9.3 E-19
6.0 E 02	6.8 E-18	1.8 E-18	7.2 E-19
8.0 E 02	5.7 E-18	1.5 E-18	5.8 E-19
1.0 E 03	5.0 E-18	1.3 E-18	5.1 E-19

References: 2^1P state below 150 keV, J. T. Park and F. D. Showengerdt, Phys. Rev. 185, 152 (1969). 3^1P and 4^1P states below 150 keV, J. Van der Bos et al., Physica 40, 357 (1968). All data above 150 keV by R. Hippler and K. H. Shartner, J. Phys. B 7, 618 (1974).

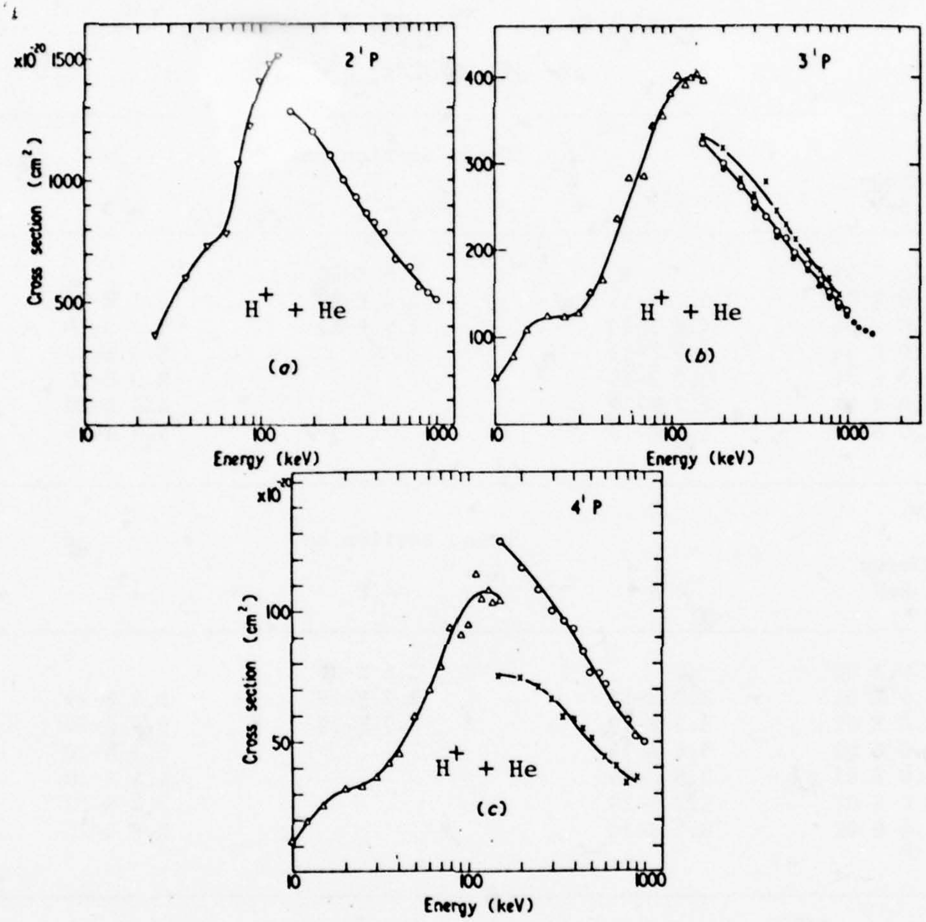
Notes:

(a) There is a clear discrepancy in absolute magnitude between the data sets at 150 keV, although the relative variation with energy seems reliable. It seems likely that the higher energy data are the more accurate.

(b) The cross sections may be reliably extrapolated to higher energies by using the formula $\sigma = \frac{A}{E} \ln B E$ where E is energy and A and B may be found by fitting to the data above 300 keV.

(c) Numerous other studies of helium excitation by H^+ have been published. Data for 4^1S and 4^1D formation is given in Vol I, pages 346 and 347. For other levels see the compilation by Thomas ("Excitation in Heavy Particle Collisions", Wiley, N. Y. 1971, pages 126 through 134).

(d) The triplet states of helium are not excited by H^+ impact.



Graphical Data B-2.29. Cross sections for formation of the He(n^1P) states by H^+ impact on He. Data shown by open points are reproduced from the table on page 1558. Other lines should be ignored.

Tabular Data B-2.30. Excitation of He by H^o impact.

$$H^o + He \rightarrow H^o + He(n^1S,\ n^1P,\ n^1D)$$

$$\rightarrow H^o + He(n^3S,\ n^3P,\ n^3D)$$

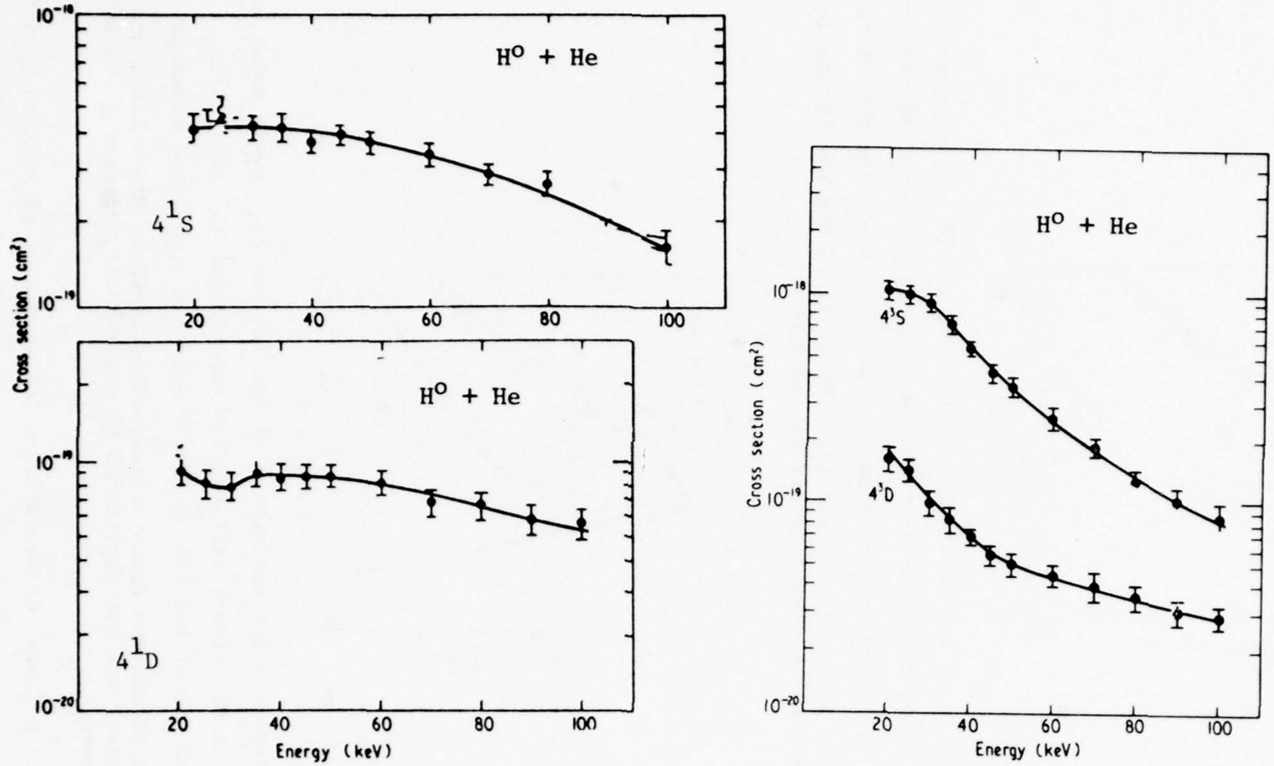
Energy keV	Cross Section cm^2 4^1S	4^1P	4^1D
1.0 E 01		2.6 E-20	
2.0 E 01	4.1 E-19	1.2 E-19	9.1 E-20
3.0 E 01	4.2 E-19	1.9 E-19	7.7 E-20
4.0 E 01	3.7 E-19		8.4 E-20
6.0 E 01	3.3 E-19		8.0 E-20
8.0 E 01	2.7 E-19		6.4 E-20
1.0 E 02	1.6 E-19		5.5 E-20

Energy keV	Cross Section cm^2 4^3S	4^3P	4^3D
1.0 E 01		3.6 E-19	
2.0 E 01	1.0 E-18	3.7 E-19	1.7 E-19
3.0 E 01	8.9 E-19	1.7 E-19	9.6 E-20
4.0 E 01	5.4 E-19		6.7 E-20
6.0 E 01	2.5 E-19		4.4 E-20
8.0 E 01	1.2 E-19		3.4 E-20
1.0 E 02	8.5 E-20		2.8 E-20

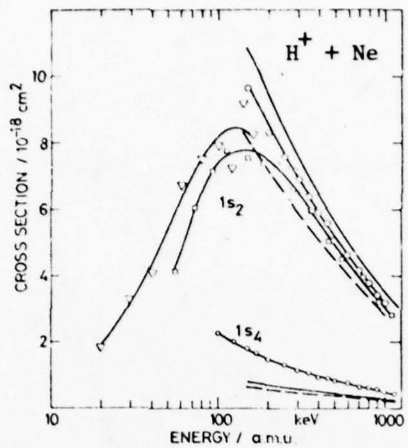
References: W. G. F. Blair and H. B. Gilbody, J. Phys. B 6, 483 (1973). J. Van Eck et al., Physica 30, 1171 (1964).

Notes: (a) These data for 4^1S, and 4^3S supersede those on pages 336 and 337 of Vol. I.

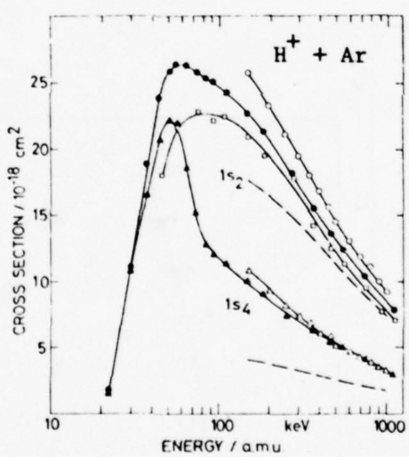
(b) Other data on formation of excited states are to be found in the compendium by Thomas ("Excitation in Heavy Particle Collisions", Wiley, N. Y. 1971, pages 137 to 139).



Graphical Data B-2.31. Cross sections for formation of the 4^1S, 4^1D, 4^3S, 4^3D states of He by H^o impact. (Tabular data are presented on page 1560).

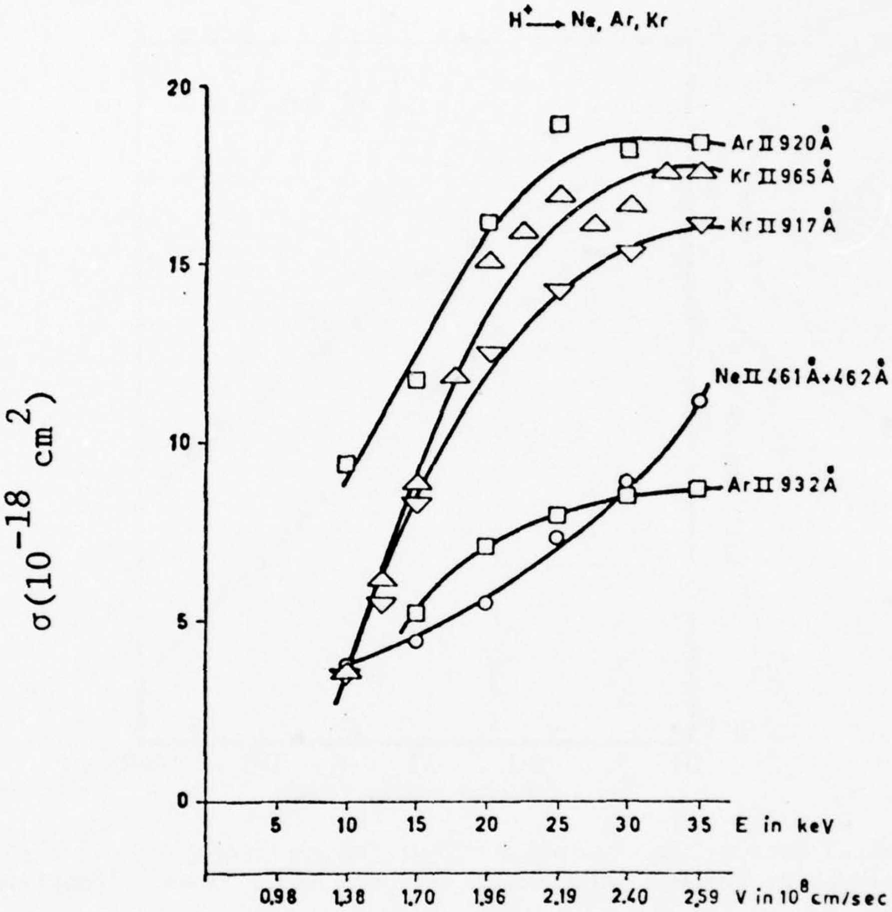


(a) Cross sections for excitation of the $1s_2$ and $1s_4$ levels shown as dashed lines and inverted triangles. Cross sections for emission of the 734 Å ($1s_2 \rightarrow$ ground state) and 744 Å ($1s_4 \rightarrow$ ground state) lines are shown as open circles. Other lines are for excitation by equivelocity electrons and may be ignored.

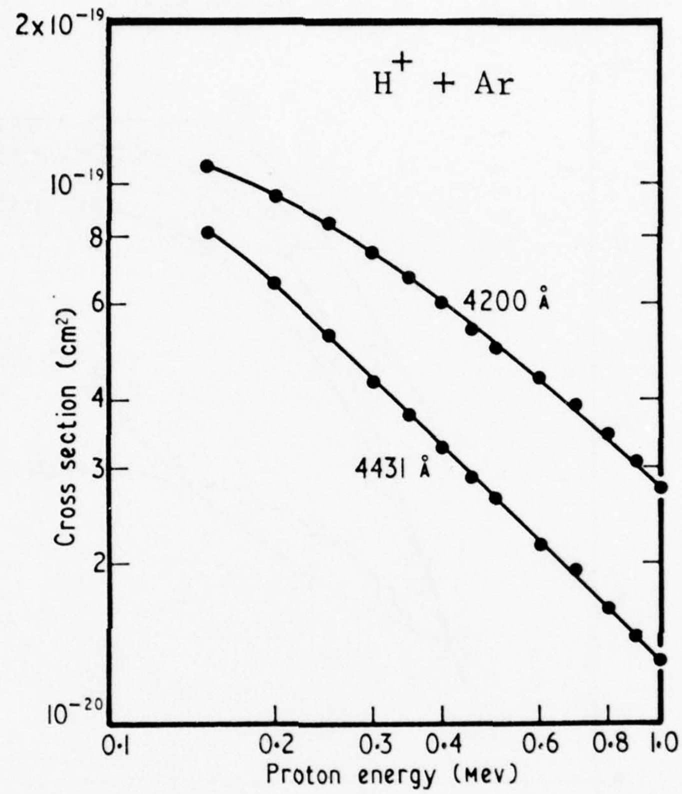


(b) Cross sections for excitation of the $1s_2$ and $1s_4$ levels shown as dashed lines. Cross sections for emission of the 1067 Å ($1s_4 \rightarrow$ ground state) and 1048 Å ($1s_2 \rightarrow$ ground state) lines shown as open triangles and open circles, respectively. Other lines and data points are for excitation by equivelocity electrons and may be ignored.

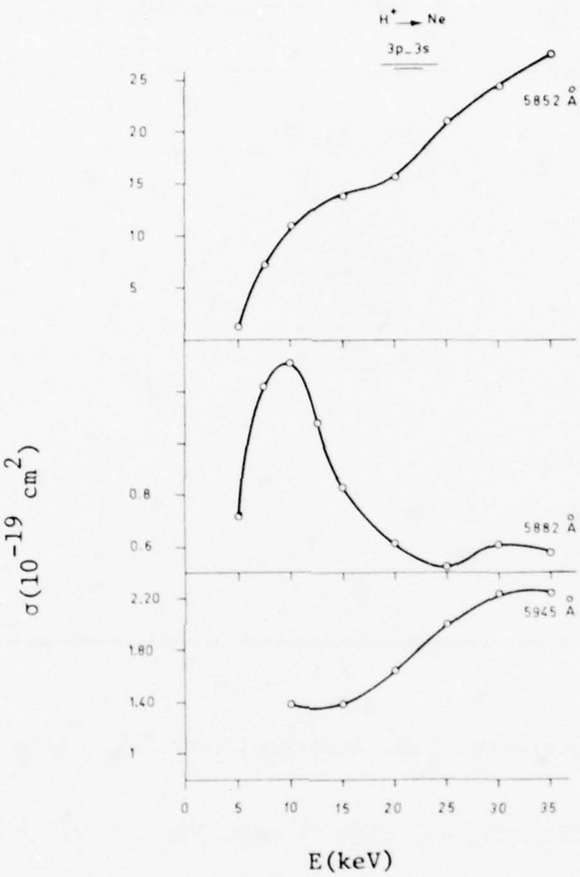
Graphical Data B-2.32. Cross sections for formation of excited Ne and Ar by H^+ impact. The data were taken from the work of Hippler and Schartner, Z. Physik 270, 225 (1974) and York et al., Phys. Rev. A 6, 1497 (1972).



Graphical Data B-2.33. Cross sections for excitation of heavy rare gases by protons — emission of Ne II, Ar II, and Kr II lines. [Cross sections for emission of certain ultraviolet lines of the singly ionized spectra induced by H^+ impact on Ne, Ar and Kr. J. van Eck et al., Phys. Rev. 130, 656 (1963). The transitions involved are $np^6\ ^2S_{1/2} \rightarrow$ ground state.]



Graphical Data B-2.34. Cross sections for excitation of heavy rare gases by protons — emission of Ar I and Ar II lines. [Emission cross sections for the Ar I 4200 Å ($5p^2 \rightarrow 4s$) and Ar II 4431 Å ($4p\ ^4P^o_{5/2} \rightarrow 3d\ ^4D_{5/2}$) lines by H^+ impact on Ar. E. W. Thomas, J. Phys. B 2, 625 (1969).]



Graphical Data B-2.35. Cross sections for excitation of heavy rare gases by protons - emission of Ne I lines. [Emission cross sections of certain Ne I 3p → 3s transitions by H^+ impact on Ne. F. J. de Heer and J. Van Eck "Atomic Collision Processes," North Holland Publishing Co., Amsterdam, 635 (1964). Note that this paper has additional data on other Ne I lines.]

Tabular Data B-2.36. Cross sections for emission of the 1606 Å and 4180 Å H_2 bands by H^+ impact.

Energy (keV)	Emission Cross Section (cm^2) 1606 Å Band	4180 Å Band
2.0 E 01	3.3 E-18	
3.0 E 01	4.5 E-18	
4.0 E 01	5.0 E-18	
5.0 E 01	5.2 E-18	
6.0 E 01	5.2 E-18	
8.0 E 01	5.0 E-18	
1.0 E 02	4.7 E-18	
1.5 E 02		8.0 E-21
2.0 E 02		6.3 E-21
3.0 E 02		4.3 E-21
4.0 E 02		3.2 E-21
5.0 E 02		2.5 E-21
6.0 E 02		2.1 E-21
8.0 E 02		1.6 E-21
9.0 E 02		1.4 E-21

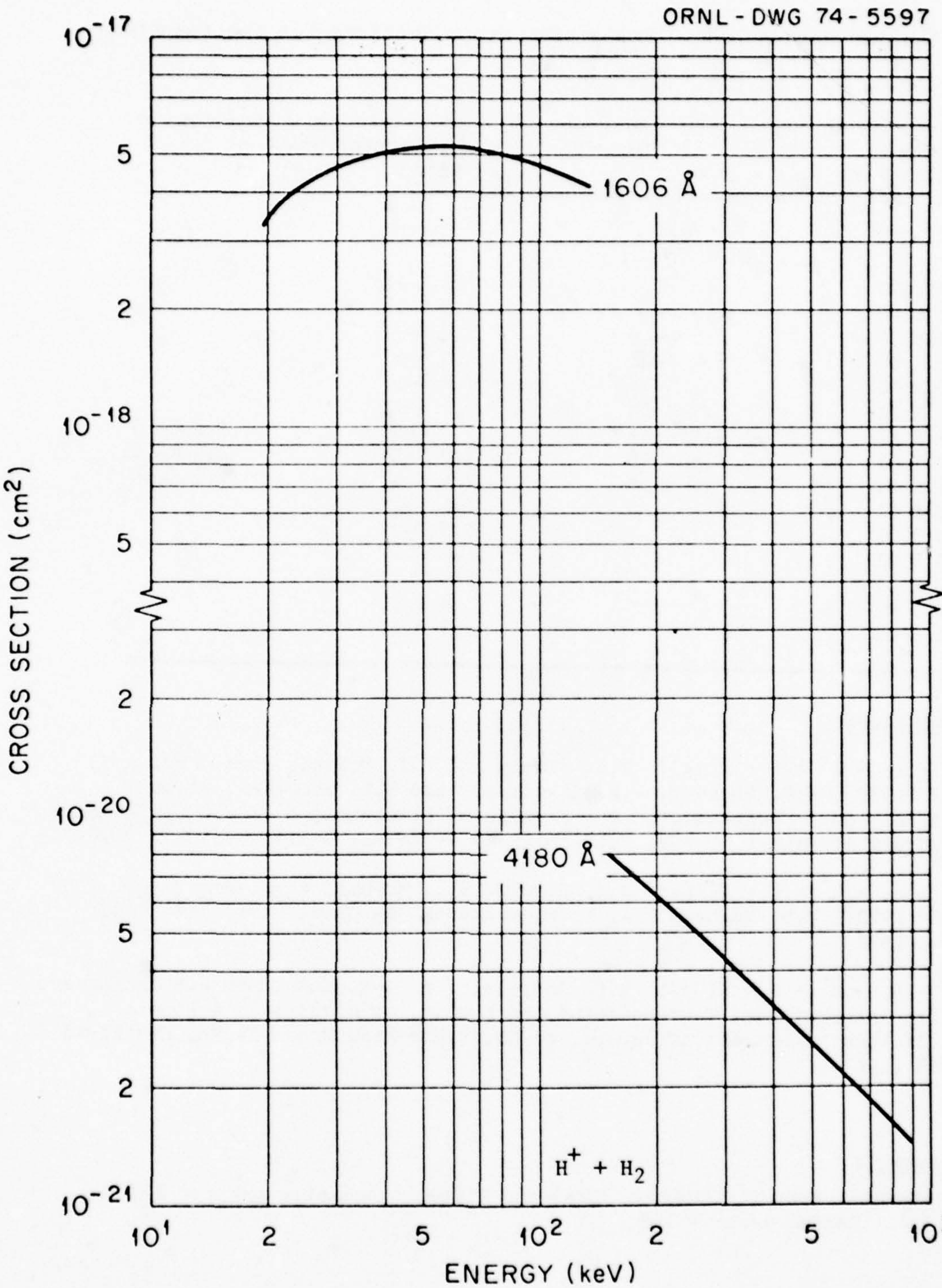
References:

1606 Å Band: D.A. Dahlberg, D.K. Anderson, and I.E. Dayton, Phys. Rev. 170, 127 (1968).

4180 Å Band: J.L. Edwards, and E.W. Thomas, Phys. Rev. 165, 16 (1968).

Accuracy:

Systematic error < 50% for 1606 Å band; systematic error < 20% for 4180 Å band. Random error < 10%.



Graphical Data B-2.37. Cross sections for emission of certain molecular hydrogen bands due to H^+ impact on H_2. (Tabular data are presented on page 1566).

Tabular Data B-2.38. Excitation cross sections for the reactions $H^+ + H_2 \rightarrow H^+ + H + H(2s,2p,3p)$.

Energy (keV)	Cross Sections for Excited State nℓ (cm^2)		
	2s	2p	3p
4.0 E 00		7.0 E-18	
5.0 E 00	1.3 E-18	9.3 E-18	
6.0 E 00	2.6 E-18	1.4 E-17	
7.0 E 00	3.5 E-18	1.8 E-17	
8.0 E 00	4.1 E-18	2.2 E-17	
1.0 E 01	4.7 E-18	2.8 E-17	
1.5 E 01	5.8 E-18	3.2 E-17	2.0 E-18
2.0 E 01	6.4 E-18	3.0 E-17	2.4 E-18
3.0 E 01	7.2 E-18	2.5 E-17	1.2 E-18
4.0 E 01		2.1 E-17	
5.0 E 01		1.8 E-17	
6.0 E 01		1.6 E-17	
7.0 E 01		1.5 E-17	
8.0 E 01		1.4 E-17	
1.0 E 02		1.2 E-17	

References:

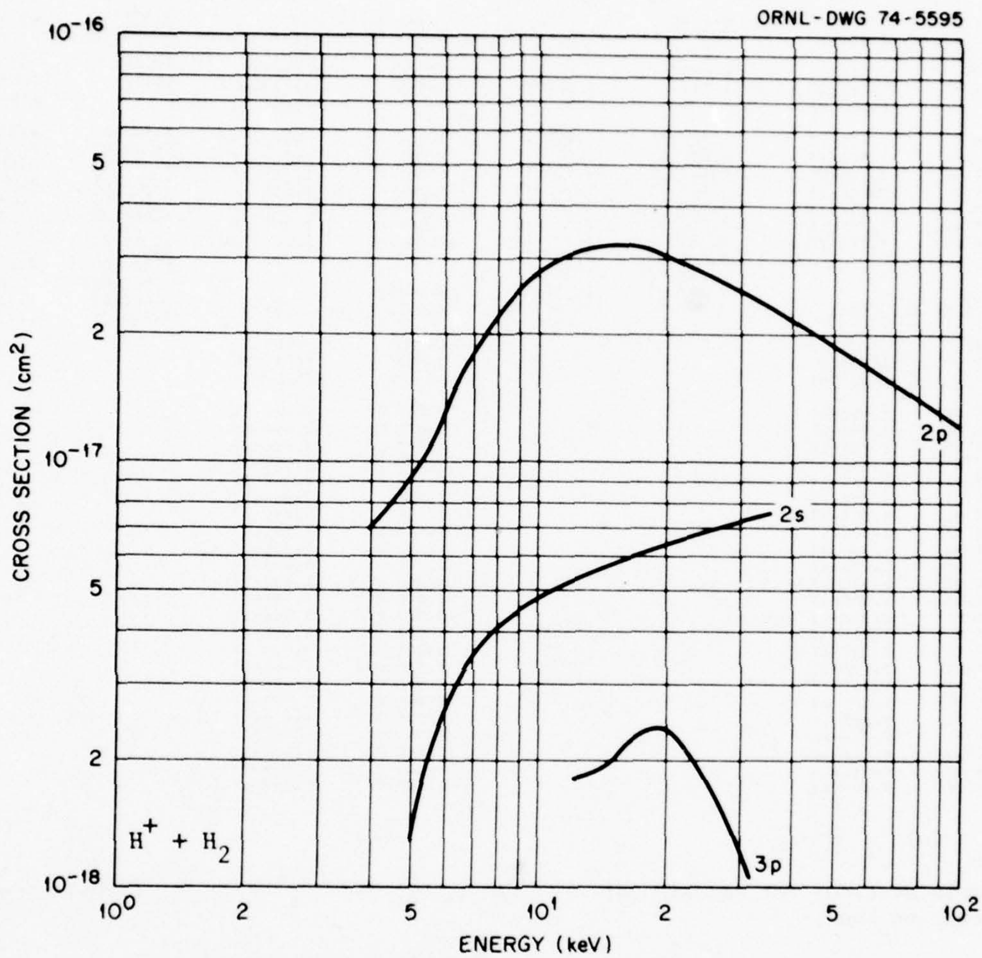
$H^+ + H_2 \rightarrow H^+ + H + H(2s)$: J.H. Birely and R.J. McNeal, Phys. Rev. A 5, 692 (1972); E.P. Andreev, V.A. Ankudinov, and S.V. Bobashev, Fifth International Conference on the Physics of Electronic & Atomic Collisions: Abstract of Papers, p.309, Publishing House Nauka, Leningrad, USSR (1967).

$H^+ + H_2 \rightarrow H^+ + H + H(2p)$: J.H. Birely, R.J. McNeal, Phys. Rev. A 5, 692 (1972); R.H. Hughes, T.J. King, and Song-Sik Choe, Phys. Rev. A 5, 644 (1972).

$H^+ + H_2 \rightarrow H^+ + H + H(3p)$: E.P. Andreev, V.A. Ankudinov, and S.V. Bobashev, Fifth International Conference on the Physics of Electronic & Atomic Collisions: Abstract of Papers, p.309, Publishing House Nauka, Leningrad, USSR (1967).

Accuracy:

Systematic error < 50% for H(2s) and H(2p); systematic error < 20% for H(3p). Random error < 10%.



Graphical Data B-2.39. Cross sections for formation of excited H in the target when protons are incident on H_2. (Tabular data are presented on page 1568).

Tabular Data B-2.40. Cross sections for excitation of molecular oxygen by H^+ impact.

8-4-6A
DUFAY ET AL. (178)

ENERGY (KEV)	CROSS SECTION (SQ. CM)
2.00E 01	1.60E-17
3.00E 01	1.30E-17
5.00E 01	1.10E-17
8.00E 01	9.70E-18
1.50E 02	8.75E-18
3.00E 02	7.85E-18
5.00E 02	7.30E-18

8-4-6B
HUGHES ET AL. (185)

ENERGY (KEV)	CROSS SECTION (SQ. CM)
5.00E 00	1.45E-17
6.00E 00	1.57E-17
8.00E 00	1.77E-17
1.00E 01	1.88E-17
1.10E 01	1.92E-17
1.20E 01	1.88E-17
1.30E 01	1.86E-17
1.40E 01	1.82E-17
1.50E 01	1.77E-17
1.60E 01	1.70E-17
1.80E 01	1.63E-17
2.00E 01	1.57E-17
3.00E 01	1.35E-17
4.00E 01	1.21E-17
5.00E 01	1.13E-17
6.00E 01	1.09E-17
7.00E 01	1.04E-17
8.00E 01	1.02E-17
9.00E 01	9.8[illegible]E-18
1.00E 02	9.76E-18
1.10E 02	9.60E-18
1.20E 02	9.43E-18
1.30E 02	9.14E-18

8-4-6C
THOMAS ET AL. (230)

ENERGY (KEV)	CROSS SECTION (SQ. CM)
1.50E 02	5.94E-18
2.00E 02	5.04E-18
2.50E 02	4.10E-18
3.00E 02	3.91E-18
3.50E 02	3.50E-18
4.00E 02	3.25E-18
4.50E 02	3.23E-18
5.00E 02	2.83E-18
6.00E 02	2.74E-18
7.00E 02	2.51E-18
8.00E 02	2.34E-18

(a)

8-4-13A
DUFAY ET AL. (178)

ENERGY (KEV)	CROSS SECTION (SQ. CM)
2.00E 01	2.70E-17
3.00E 01	2.20E-17
5.00E 01	1.80E-17
8.00E 01	1.60E-17
1.50E 02	1.45E-17
3.00E 02	1.30E-17
5.00E 02	1.20E-17

8-4-13B
HUGHES ET AL. (185)

ENERGY (KEV)	CROSS SECTION (SQ. CM)
5.00E 00	2.21E-17
6.00E 00	2.40E-17
8.00E 00	2.71E-17
1.00E 01	2.86E-17
1.10E 01	2.94E-17
1.20E 01	2.86E-17
1.30E 01	2.84E-17
1.40E 01	2.79E-17
1.50E 01	2.71E-17
1.60E 01	2.60E-17
1.80E 01	2.50E-17
2.00E 01	2.40E-17
3.00E 01	2.06E-17
4.00E 01	1.84E-17
5.00E 01	1.72E-17
6.00E 01	1.66E-17
7.00E 01	1.59E-17
8.00E 01	1.55E-17
9.00E 01	1.51E-17
1.00E 02	1.49E-17
1.10E 02	1.47E-17
1.20E 02	1.44E-17
1.30E 02	1.39E-17

8-4-13C
THOMAS ET AL. (230)

ENERGY (KEV)	CROSS SECTION (SQ. CM)
1.50E 02	9.50E-18
2.00E 02	8.10E-18
2.50E 02	6.60E-18
3.00E 02	6.30E-18
3.50E 02	5.60E-18
4.00E 02	5.20E-18
4.50E 02	5.20E-18
5.00E 02	4.50E-18
6.00E 02	4.40E-18
7.00E 02	4.00E-18
8.00E 02	3.70E-18
9.00E 02	3.50E-18

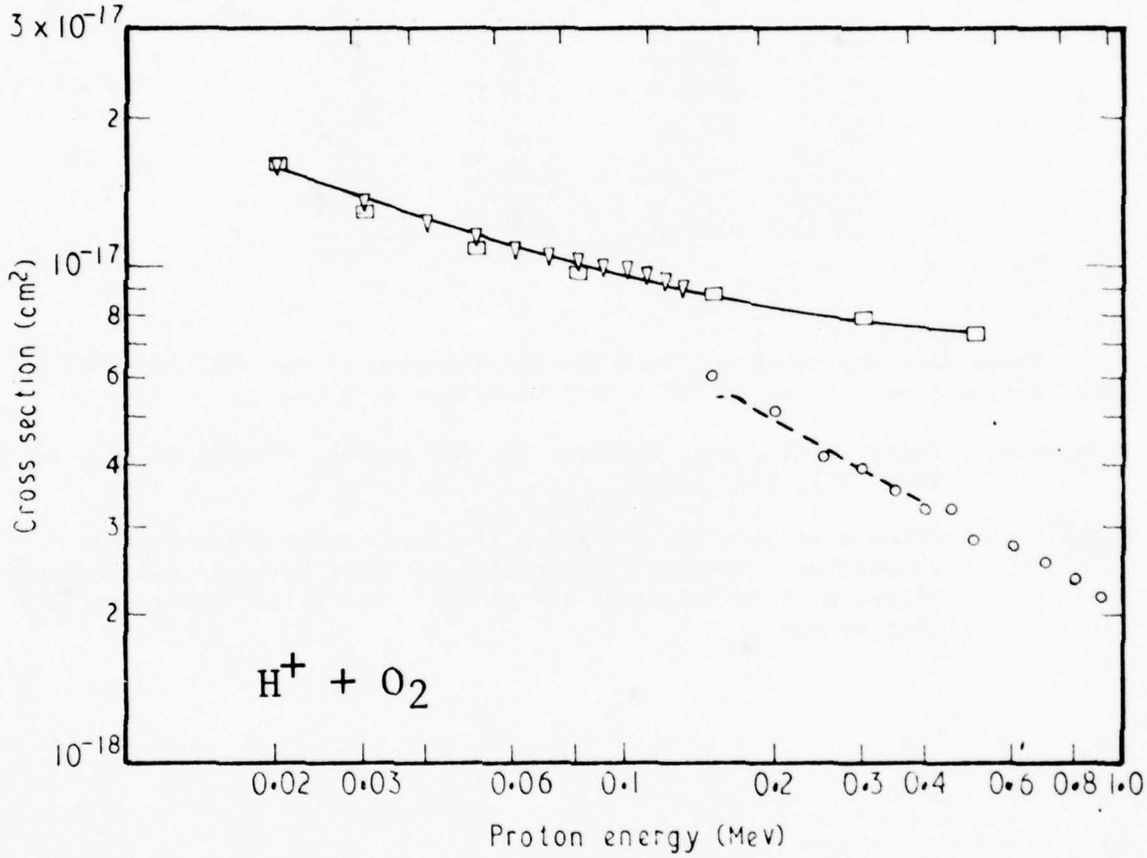
(b)

(a) Cross sections for emission of the 5632 Å, O_2^+ [b $^4\Sigma_g^-$ → a $^4\Pi_u$ (1,0)] first negative band.

(b) Cross sections for excitation of the O_2^+ [$b^4\Sigma_g^-$ (v=1)] level.

References: Dufay et al., Ann. Geophys. 22, 615 (1966). Hughes et al., Phys. Rev. 136, A1222 (1964), Thomas et al., J. Phys. B 1, 233 (1968).

Notes: Numerous other data sets for other levels are to be found in the compendium by Thomas ("Excitation in Heavy Particle Collisions", Wiley, N. Y., 1972) pages 288 to 292. The above tables are from this source.



Graphical Data B-2.41. Cross sections for emission of the 5632 Å O_2^+ first negative band excited by H^+ on O_2. Partial representation of data from table (a) on page 1570.

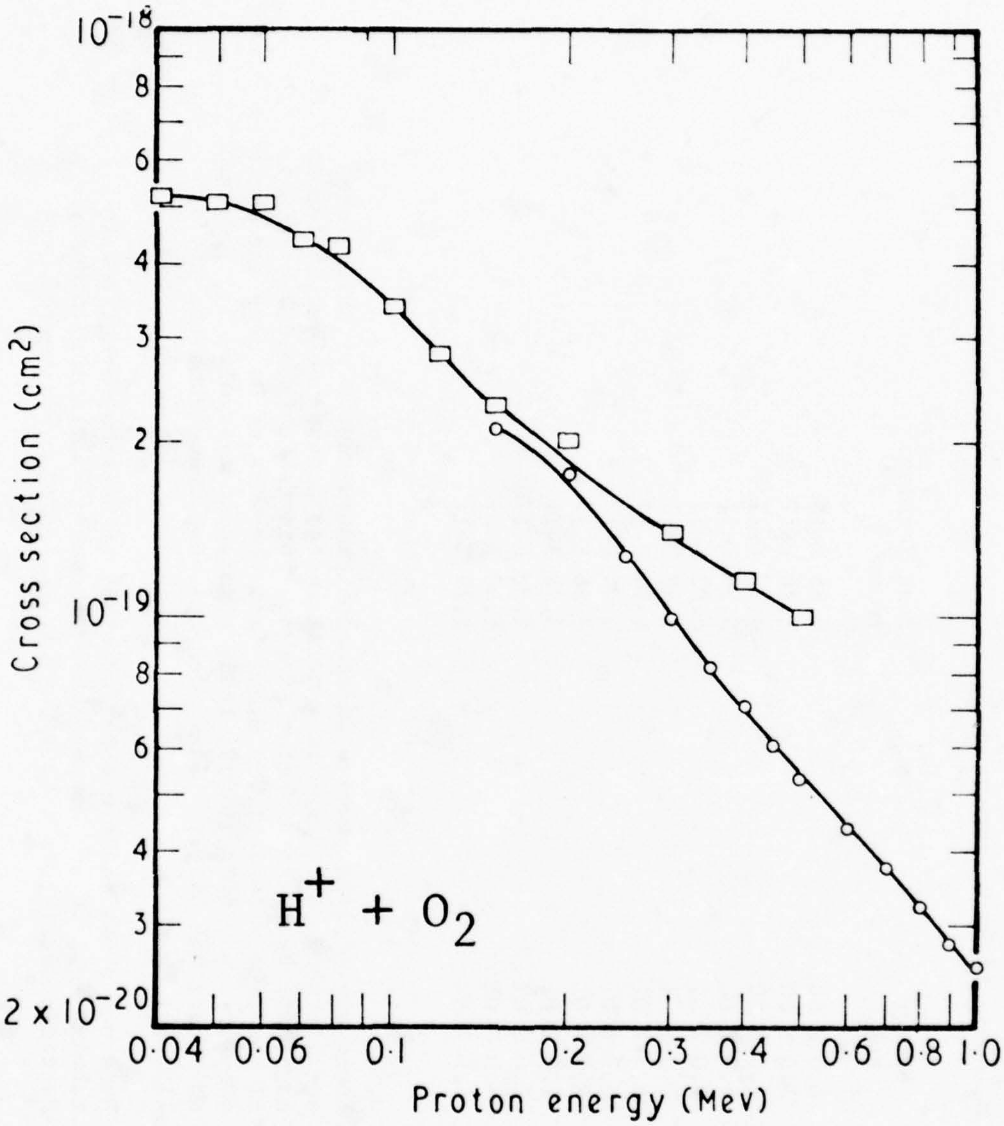
Tabular Data B-2.42. Cross sections for excitation of the 4416 Å O II line by H^+ impact on O_2.

B-4-2A DUFAY ET AL. (178)		B-4-2C THOMAS ET AL. (230)	
ENERGY (KEV)	CROSS SECTION (SQ. CM)	ENERGY (KEV)	CROSS SECTION (SQ. CM)
4.00E 01	5.20E-19	1.50E 02	2.09E-19
5.00E 01	5.10E-19	2.00E 02	1.76E-19
6.00E 01	5.10E-19	2.50E 02	1.27E-19
7.00E 01	4.40E-19	3.00E 02	1.00E-19
8.00E 01	4.30E-19	3.50E 02	8.20E-20
1.00E 02	3.40E-19	4.00E 02	7.00E-20
1.20E 02	3.80E-19	4.50E 02	6.00E-20
1.50E 02	2.30E-19	5.00E 02	5.30E-20
2.00E 02	2.00E-19	6.00E 02	4.40E-20
3.00E 02	1.40E-19	7.00E 02	3.70E-20
4.00E 02	1.15E-19	8.00E 02	3.20E-20
5.00E 02	1.00E-19	9.00E 02	2.80E-20
		1.00E 03	2.50E-20

These data are cross sections for the emission of the 4415 and 4417 Å lines (unresolved) in the 3p $^2D^o \rightarrow 3s^2P$ multiplet of O II.

References: Dufay et al., Ann. Geophys. 22, 615 (1966). Thomas et al., J. Phys. B 1, 233 (1968).

Notes: Other data sets for O I and O II lines can be found in the compendium by Thomas ("Excitation in Heavy Particle Collisions", Wiley, N. Y. 1972) pages 288 to 292. The above tables are from this source.



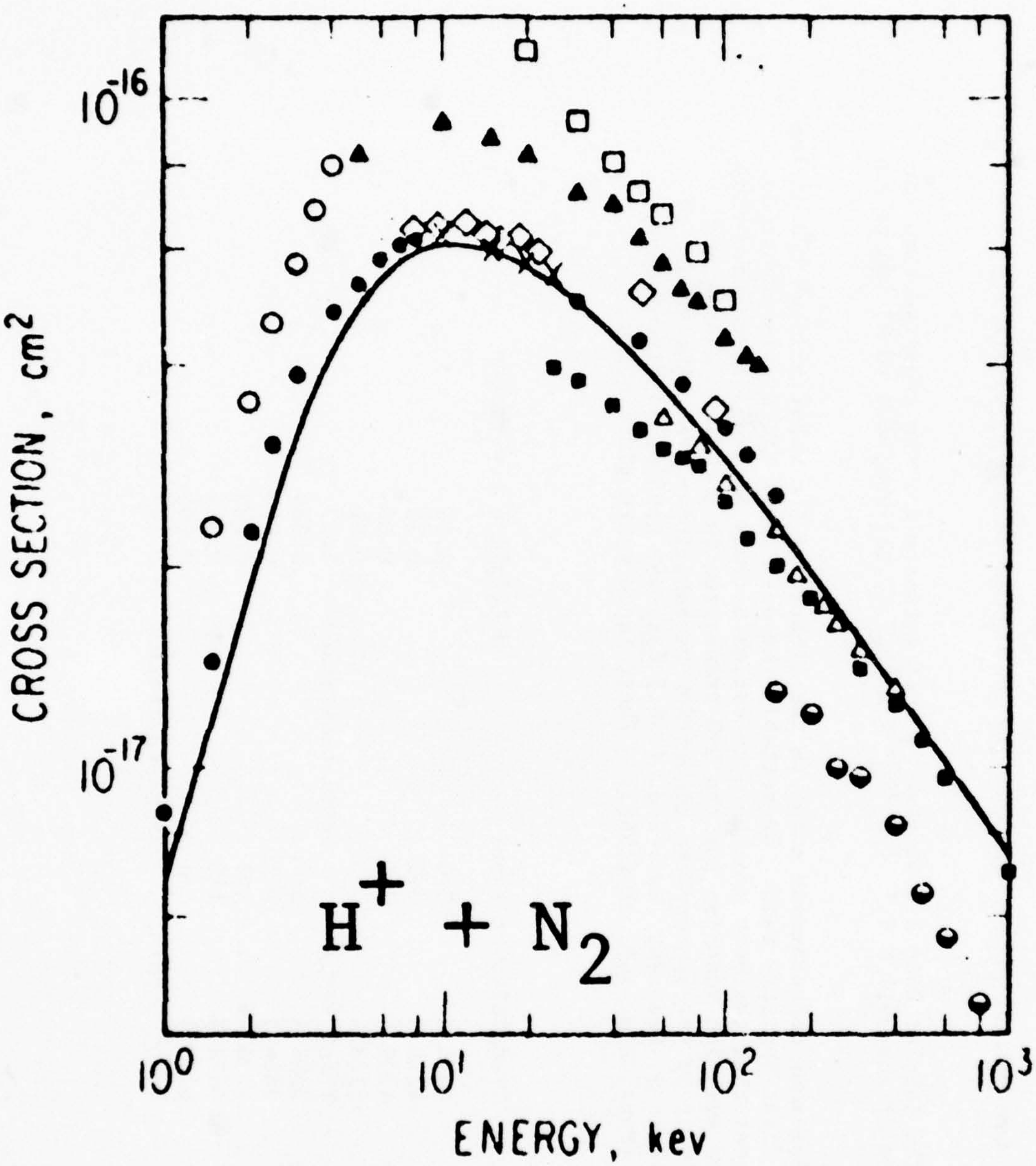
Graphical Data B-2.43. Cross sections for emission of the 4415 and 4417 Å lines (unresolved) of O II by H^+ impact on O_2. (Tabular data are presented on page 1572).

Tabular Data B-2.44. Cross sections for emission of the 3914 Å $B\ {}^2\Sigma_u^+ \rightarrow X\ {}^2\Sigma_g^+$ (0,0) first negative band of N_2^+ induced by H^+ impact on N_2.

Energy keV	Cross Section cm^2
1.0 E 00	8.65 E-18
2.0 E 00	2.20 E-17
4.0 E 00	4.77 E-17
5.0 E 00	5.22 E-17
1.0 E 01	6.02 E-17
2.0 E 01	5.49 E-17
4.0 E 01	4.79 E-17
6.0 E 01	4.04 E-17
8.0 E 01	3.56 E-17
1.0 E 02	3.24 E-17
2.0 E 02	2.33 E-17
4.0 E 02	1.60 E-17
6.0 E 02	1.29 E-17

Notes: (a) There are at least twelve independent measurements of this cross section which all agree in general energy dependance but differ in magnitude by up to a factor of two. This table is a best estimate of the true value. It is drawn from the work of De Heer and Aarts (Physica, 48, 620 (1970)); it is consistent also with the judgement of McNeal and Birely. (Rev. Geophys. and Space Physics, 11, 633 (1973)).

(b) Numerous other measurements for other transitions are given in tabular form in the compendium by Thomas ("Excitation in Heavy Particle Collisions", Wiley, N. Y. 1972) pages 269 to 283.



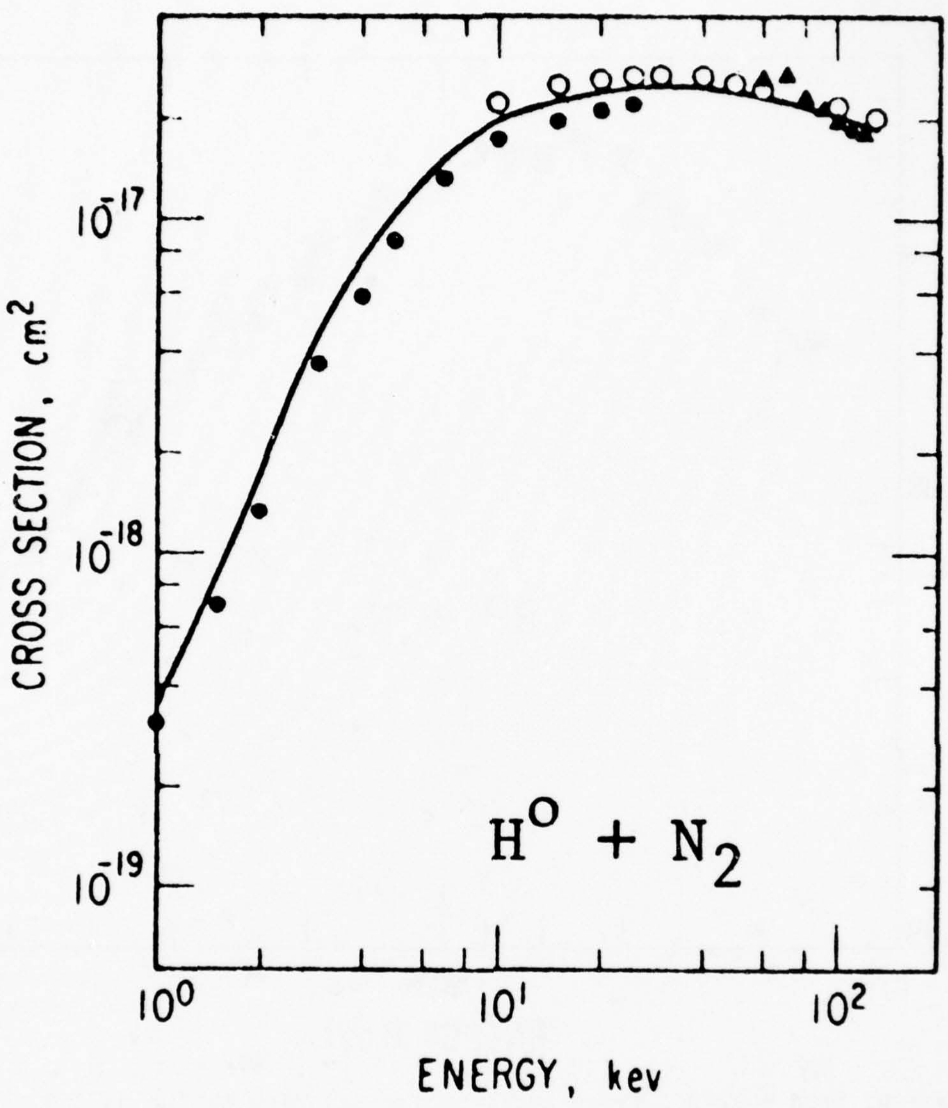
Graphical Data B-2.45. Compendium of data for emission of the 3914 Å N_2^+ transition induced by H^+ impact on N_2. The figure is from McNeal and Birely (Rev. Geophys. and Space Physics); the solid line is adjusted to be a best estimate of cross section and is consistent with the tabular data on page 1574).

Scaling Law B-2.46. Cross sections for excitation of N_2^+ by proton impact on N_2.

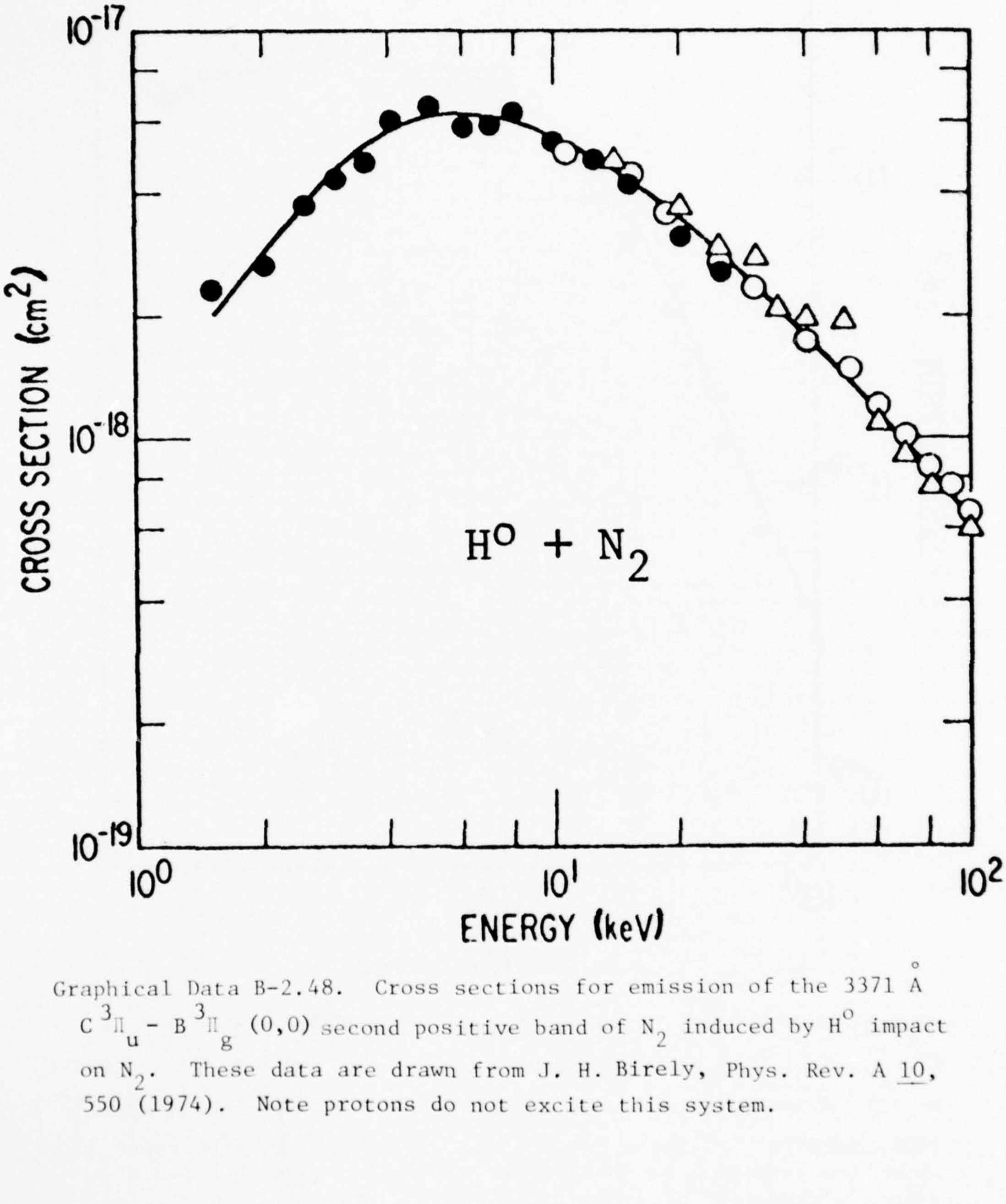
The Tabular Data B-2.44 give a best estimate for the cross section for emission of the 3914 Å N_2^+ [$B\ ^2\Sigma_u^+ \rightarrow X\ ^2\Sigma_g^+$ (0,0)] band due to H^+ impact on N_2.

Numerous measurements exist in the literature for other v' → v" transition in the First Negative Band. Regrettably the data often differ in magnitude. We suggest that the best procedure to estimate cross sections is to take the measured emission function for the 0→0 transition in the Table B-2.44 and multiply it by the appropriate transition probabilities (from the theory of Nicholls in J. Res. Nat. Bur. Std. (U.S.) 65A, 451 (1961)) as discussed by Thomas (Phys. Rev. 165, 32 (1968)). These factors are given below.

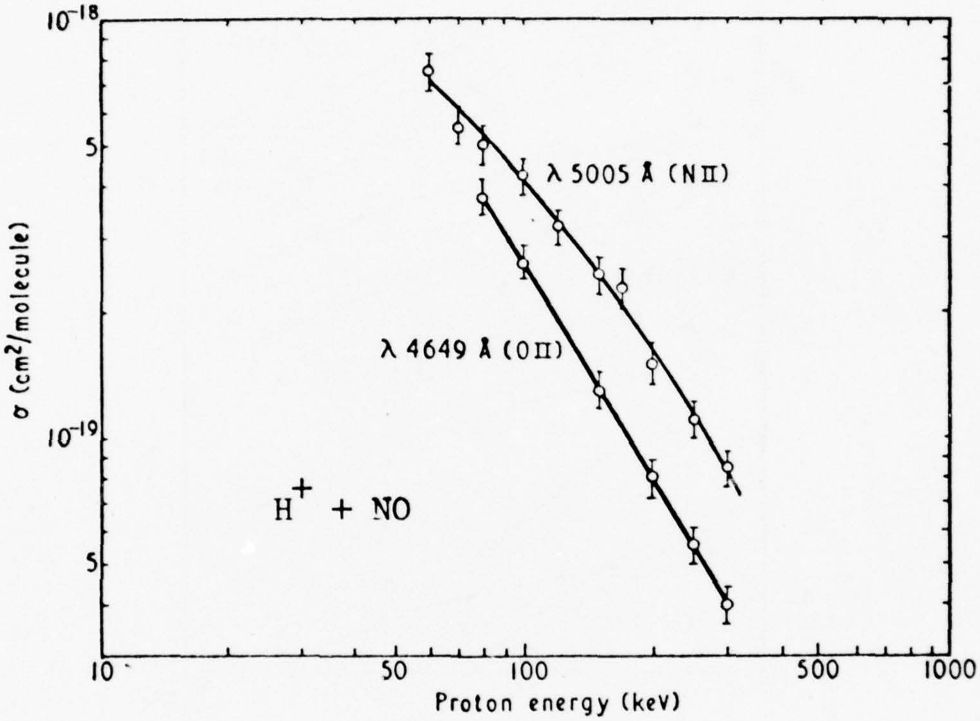
Transition or level			Multiplicative factor
3914 Å	0→0		1.00
4278 Å	0→1		0.30
4709 Å	0→2		0.06
5228 Å	0→3		0.01
$B^2\Sigma_u^+$ (v=0)		level excitation	1.37
3582 Å	1→0		0.068
3884 Å	1→1		0.040
4236 Å	1→2		0.039
4652 Å	1→3		0.014
5149 Å	1→4		0.003
$B^2\Sigma_u^+$ (v=0)		level excitation	0.164



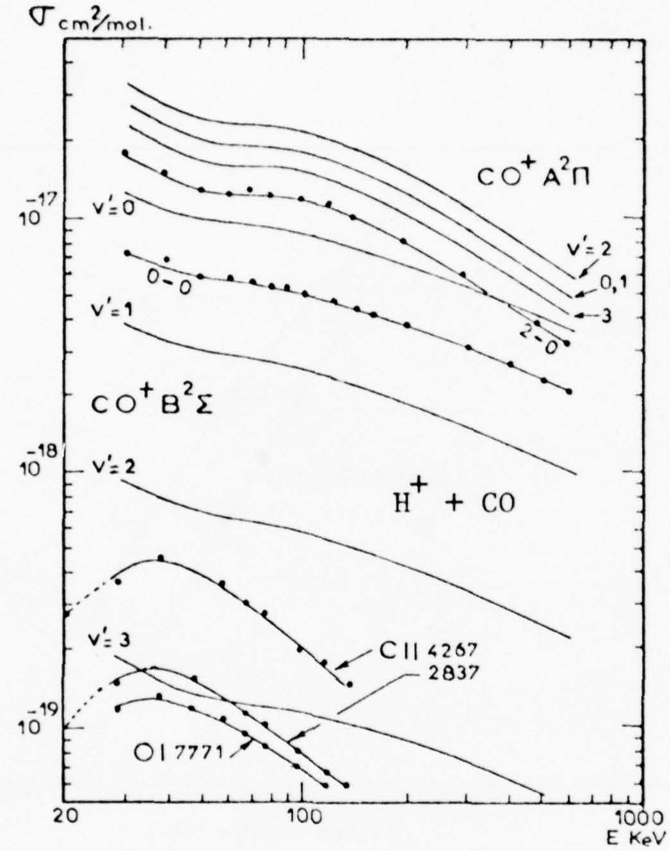
Graphical Data B-2.47. Cross sections for emission of the 3916 Å $B\,^2\Sigma_u^+ \rightarrow X\,^2\Sigma_g^+$ (0,0) first negative band of N_2^+ induced by H^O impact on N_2. These data are drawn from the review by McNeal and Birely [Rev. Geophys. and Space Physics 11, 633 (1973)] and represent an objective judgement as to the best data. To estimate cross sections for emission of other transitions in this system, or for excitation of specific levels, we suggest use of the above data with the multiplicative factors shown in the Scaling Law B-2.46.



Graphical Data B-2.48. Cross sections for emission of the 3371 Å $C\,^3\Pi_u - B\,^3\Pi_g$ (0,0) second positive band of N_2 induced by H^0 impact on N_2. These data are drawn from J. H. Birely, Phys. Rev. A 10, 550 (1974). Note protons do not excite this system.



Graphical Data B-2.49. Cross sections for emission of the 5005 Å N II and 4649 Å O II lines induced by H$^+$ impact on NO. From J. M. Robinson and H. B. Gilbody, Proc. Phys. Soc. (London) 92, 589 (1967).



Graphical Data B-2.50. Cross sections for various emissions induced by H^+ impact on CO. The lower three curves with data points are for emission of the 2837 and 4267 Å lines of O II and the 7771 Å line of O I. The upper two curves with data points are emission cross sections for the 0-0 band in the first negative system of CO^+ and the 2-0 band in the comet trail system of CO^+. Also shown (without data points) are estimates of cross sections for formulation of the v = 0, 1, 2, and 3 vibrational levels of the B $^2\Sigma$ CO^+ state and also for the v = 0, 1, 2, 3 levels of the A $^2\Pi$ CO^+ state. From Poulizac et al., Ann. Astrophys. 30, 301 (1967).

Tabular Data B-2.51. Cross sections for production of free electrons by He^+ impact on Ne, Ar, Kr, N_2, O_2. (For corresponding data on He and H_2, see Vol. I page 380.)

Energy keV	Cross Section cm^2				
	Ne	Ar	Kr	N_2	O_2
1.0 E 01	7.6 E-17	3.7 E-16	4.0 E-16	4.0 E-16	3.8 E-16
2.0 E 01	1.2 E-16	4.9 E-16	5.8 E-16	5.8 E-16	5.0 E-16
5.0 E 01	1.8 E-16	7.0 E-16	8.5 E-16	8.5 E-16	6.4 E-16
1.0 E 02	2.5 E-16	8.9 E-16	1.1 E-15	1.1 E-15	7.9 E-16
2.0 E 02	4.2 E-16	1.1 E-15	1.4 E-15	1.2 E-15	
5.0 E 02	4.1 E-16	1.0 E-15	1.3 E-15	1.0 E-15	
1.0 E 03	3.4 E-16	7.5 E-16	1.0 E-15	7.0 E-16	
1.8 E 03	2.9 E-16	5.9 E-16	8.5 E-16	6.0 E-16	

References: L. I. Pivovar et al., Soviet Physics, JETP 27, 699 (1968). F. J. De Heer et al., Physica 32, 1793 (1966).

Notes: These data represent ionization of the target, with at higher energies, a contribution from stripping of the projectile.

Tabular Data B-2.52. Cross sections for production of slow positive ions by He^+ impact on Ne, Ar, Kr, N_2, O_2. (For corresponding data on He and N_2, see Vol. I page 382.)

Energy keV	Cross Section cm^2				
	Ne	Ar	Kr	N_2	O_2
1.0 E 01	7.3 E-17	1.1 E-15	1.2 E-15	1.0 E-15	
2.0 E 02	7.4 E-17	1.2 E-15	1.4 E-15	1.3 E-15	1.3 E-15
5.0 E 01	5.8 E-17	1.4 E-15	1.6 E-15.	1.5 E-15	1.3 E-15
1.0 E 02	5.1 E-17	1.4 E-15	1.7 E-15	1.6 E-15	1.2 E-15
2.0 E 02	5.0 E-17	1.3 E-15	1.8 E-15	1.5 E-15	
5.0 E 02	3.8 E-17	9.5 E-16	1.3 E-15	9.3 E-16	
1.0 E 03	2.8 E-17	6.3 E-16	9.0 E-16	6.1 E-16	
1.8 E 03	2.2 E-17	4.5 E-16	7.5 E-16	4.5 E-16	

References: L. I. Pivovar et al., Soviet Physics, JETP 27, 699 (1968). F. J. De Heer et al., Physica 32, 1793 (1966).

Notes: These data represent ionization of the target plus a component due to electron pickup by the projectile.

Tabular Data B-2.53. Cross sections for the production of O_2^+, O^+, and O^{2+} ions by He^+ in O_2.

Energy (keV)	Cross Sections (cm^2)		
	O_2^+	O^+	O^{2+}
5.5 E 00	8.22 E-17	8.20 E-16	1.31 E-17
1.0 E 01	1.43 E-16	7.64 E-16	2.17 E-17
2.0 E 01	2.62 E-16	6.95 E-16	4.18 E-17
3.0 E 01	3.34 E-16	7.06 E-16	5.98 E-17
4.0 E 01	3.56 E-16	7.22 E-16	6.99 E-17
4.5 E 01	3.59 E-16	7.24 E-16	7.10 E-17

References:

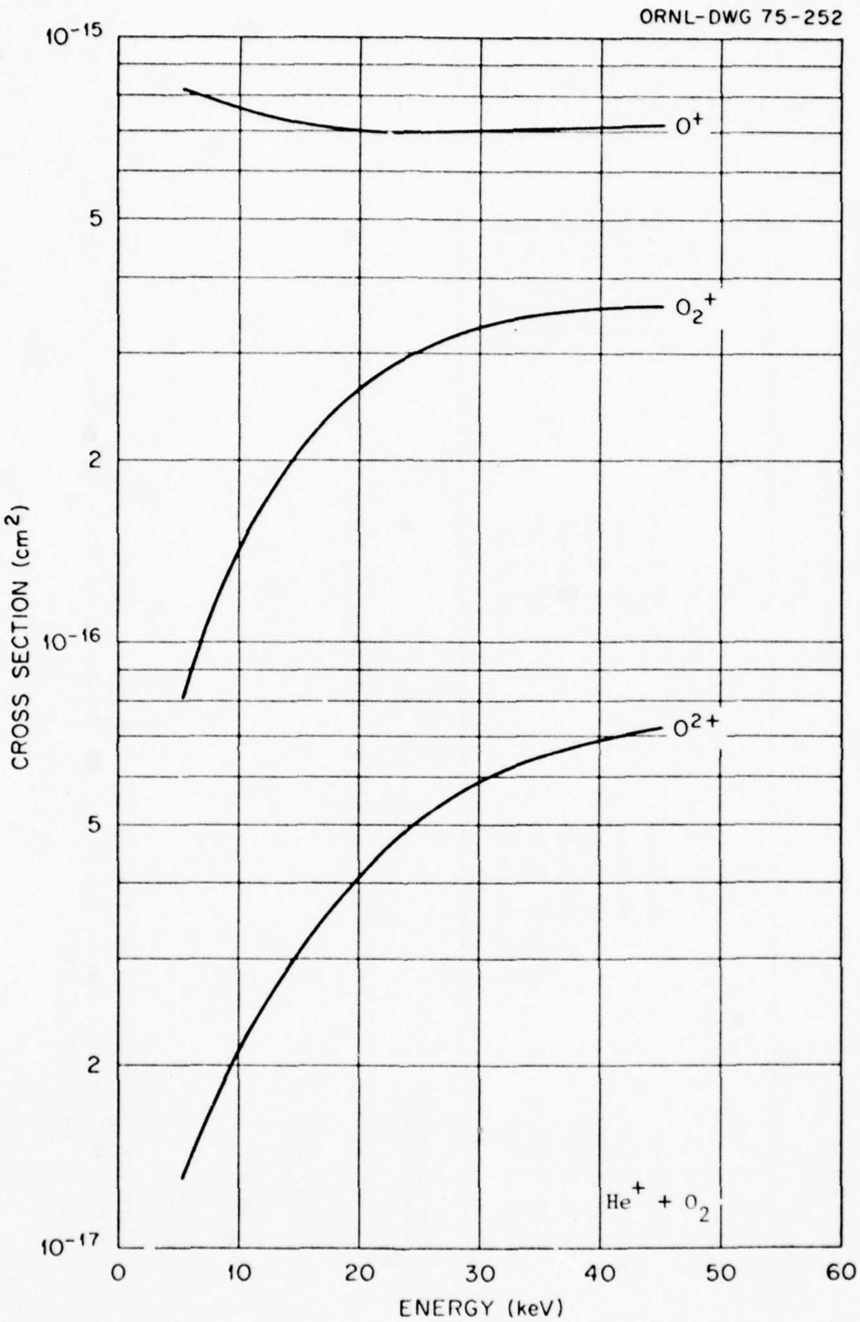
R. Browning, C.J. Latimer, and H.B. Gilbody, J. Phys. B 2, 534 (1969).

Accuracy:

± 20%.

Note:

Further information on the yield and energy distribution of fragments for 1 MeV He^+ impact is to be found in the work of M. F. Steur et al., Phys. Rev. A 18, 1873 (1977).



Graphical Data B-2.54. Cross sections for production of secondary ions by He^+ impact on O_2. (Tabular data were presented on page 1583).

Tabular Data B-2.55. Cross sections for production of N_2^+, N^+, and N^{2+} by He^+ in N_2.

Energy (keV)	Cross Sections (cm^2)		
	N_2^+	N^+	N^{2+}
5.5 E 00	7.81 E-17	5.99 E-16	1.44 E-17
1.0 E 01	1.67 E-16	5.16 E-16	2.20 E-17
2.0 E 01	3.47 E-16	5.16 E-16	4.03 E-17
3.0 E 01	4.34 E-16	5.56 E-16	5.99 E-17
4.0 E 01	4.76 E-16	6.04 E-16	7.66 E-17
4.6 E 01	4.98 E-16	6.65 E-16	8.28 E-17

References:

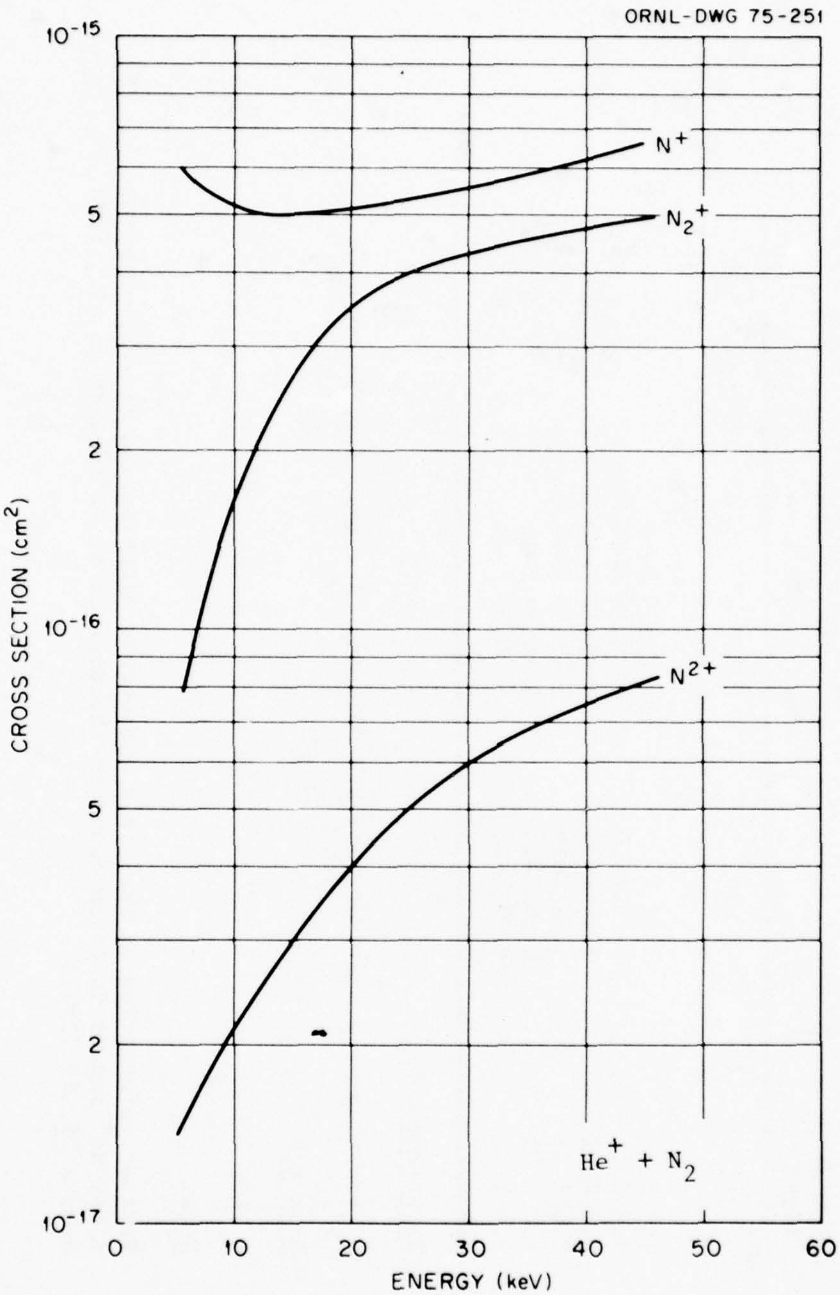
R. Browning, C.J. Latimer, and H.B. Gilbody, J. Phys. B 2, 534 (1969).

Accuracy:

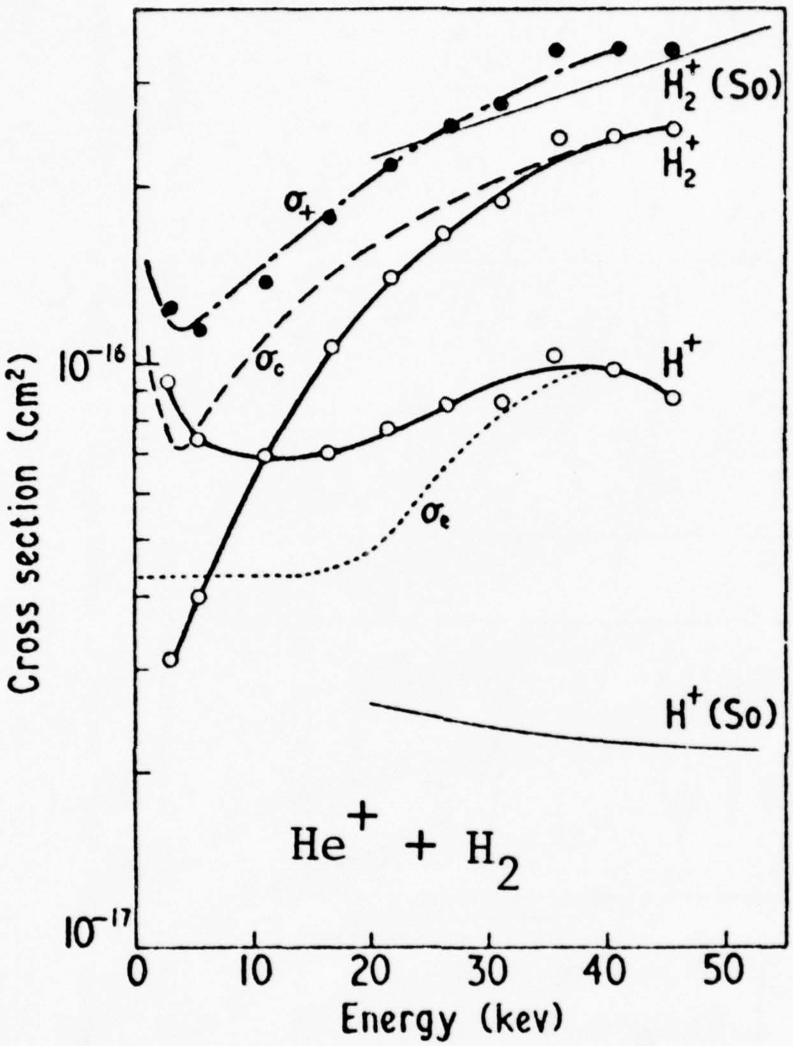
± 20%.

Note:

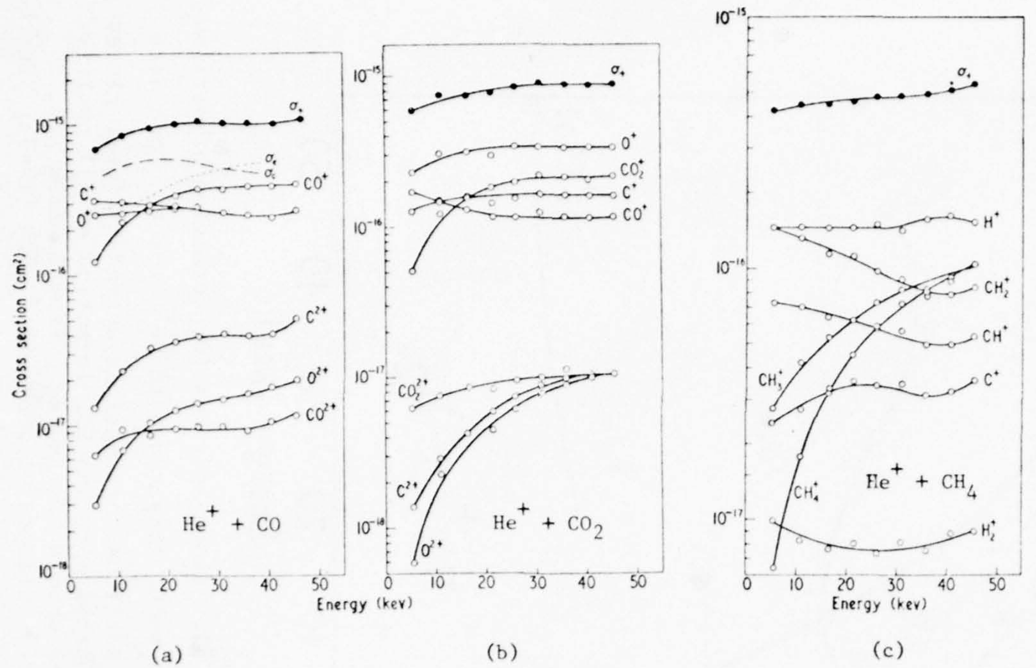
Further information on the yield and energy distribution of fragments for 1 MeV He^+ impact is to be found in the work of A. K. Edwards et al., Phys. Rev. A 15, 48 (1977).



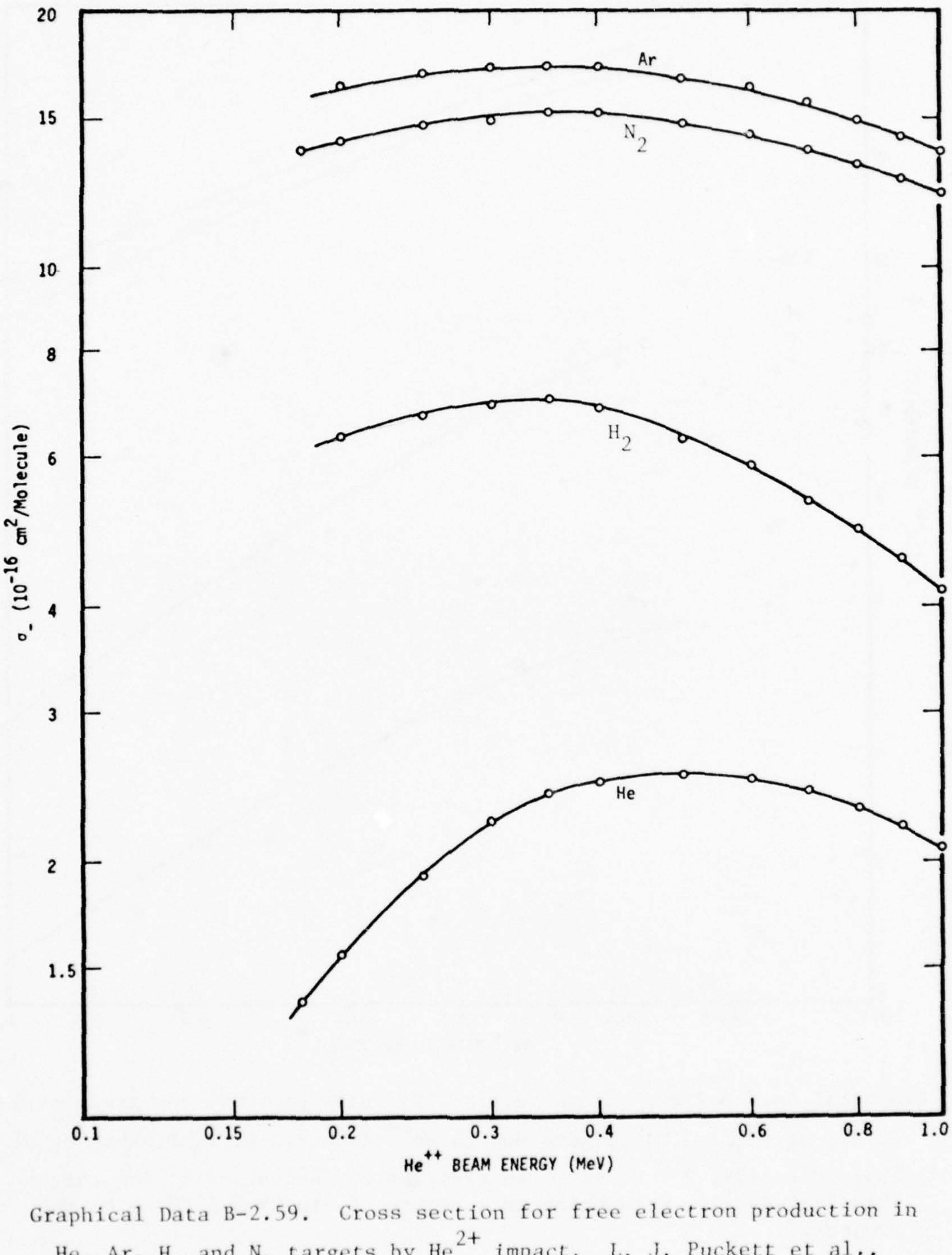
Graphical Data B-2.56. Cross sections for production of secondary ions by He^+ impact on N_2. (Tabular data were presented on page 1585).



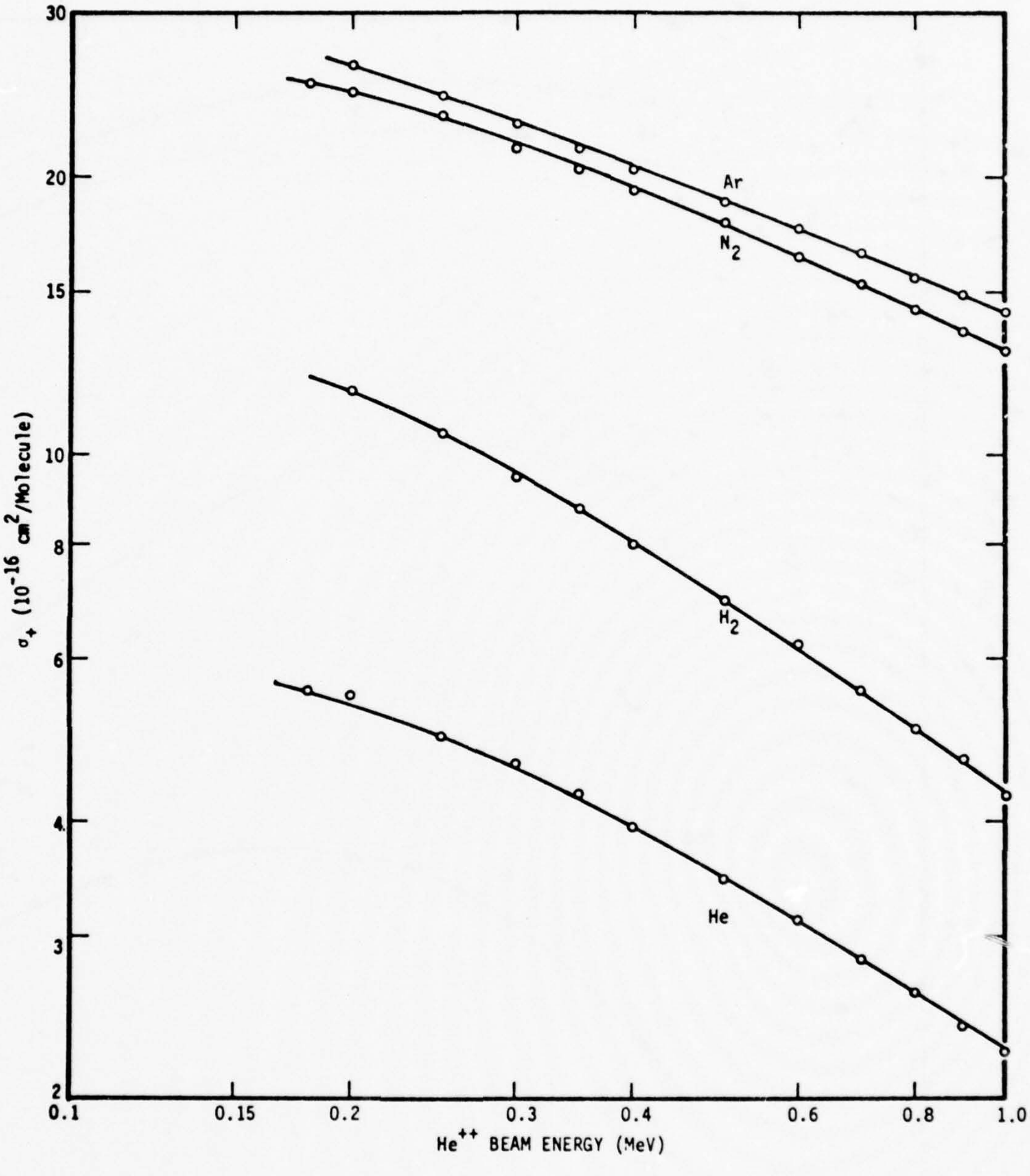
Graphical Data B-2.57. Cross sections for formation of various secondary ions in an H_2 target due to He^+ impact. Open data points are cross sections for specific secondary ions; closed points are total cross sections for formation of all positive ions. Other lines should be ignored. From R. Browning, C. J. Latimer, H. B. Gilbody, J. Phys. B 2, 534 (1969). Further information on the yield of H^+ and the kinetic energy of H^+ fragments for 0.5 to 4 MeV He^+ impact is to be found in A. K. Edwards et al., Phys. Rev. A 16, 1385 (1977).



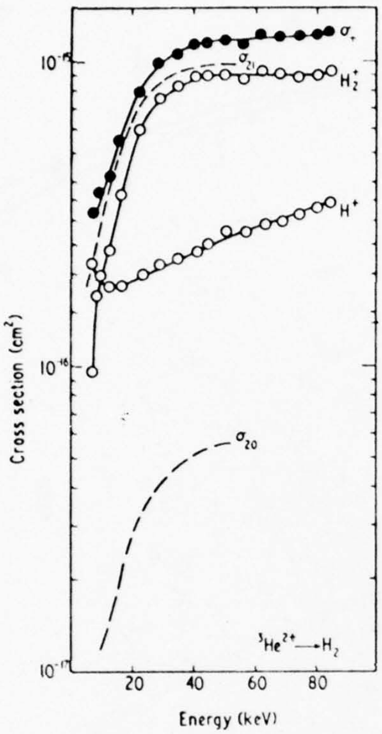
Graphical Data B-2.58. Cross sections for formation of various secondary ions by He^{+} impact on (a) CO, (b) CO_2 and (c) CH_4. Open points: secondary ion data; closed points: *total* cross section for formation of secondary ions. R. Browning, C. J. Latimer and H. B. Gilbody, J. Phys. B 2, 534 (1969).



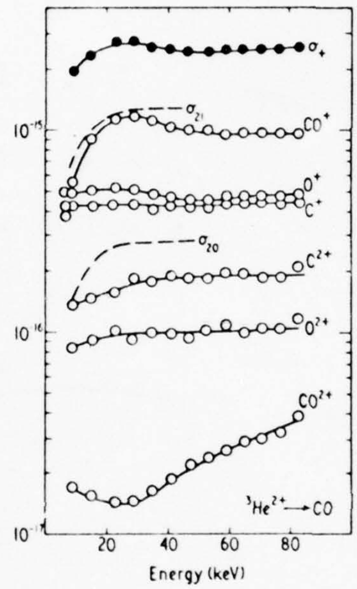
Graphical Data B-2.59. Cross section for free electron production in He, Ar, H_2, and N_2 targets by He^{2+} impact. L. J. Puckett et al., Phys. Rev. 178, 271 (1969).



Graphical Data B-2.60. Cross sections for slow positive ion production in He, Ar, H_2, and N_2 targets due to He^{2+} impact. L. J. Puckett et al., Phys. Rev. 178, 271 (1969). In addition to ionization of the target, this includes ion production as a result of electron pick up by the projectile.

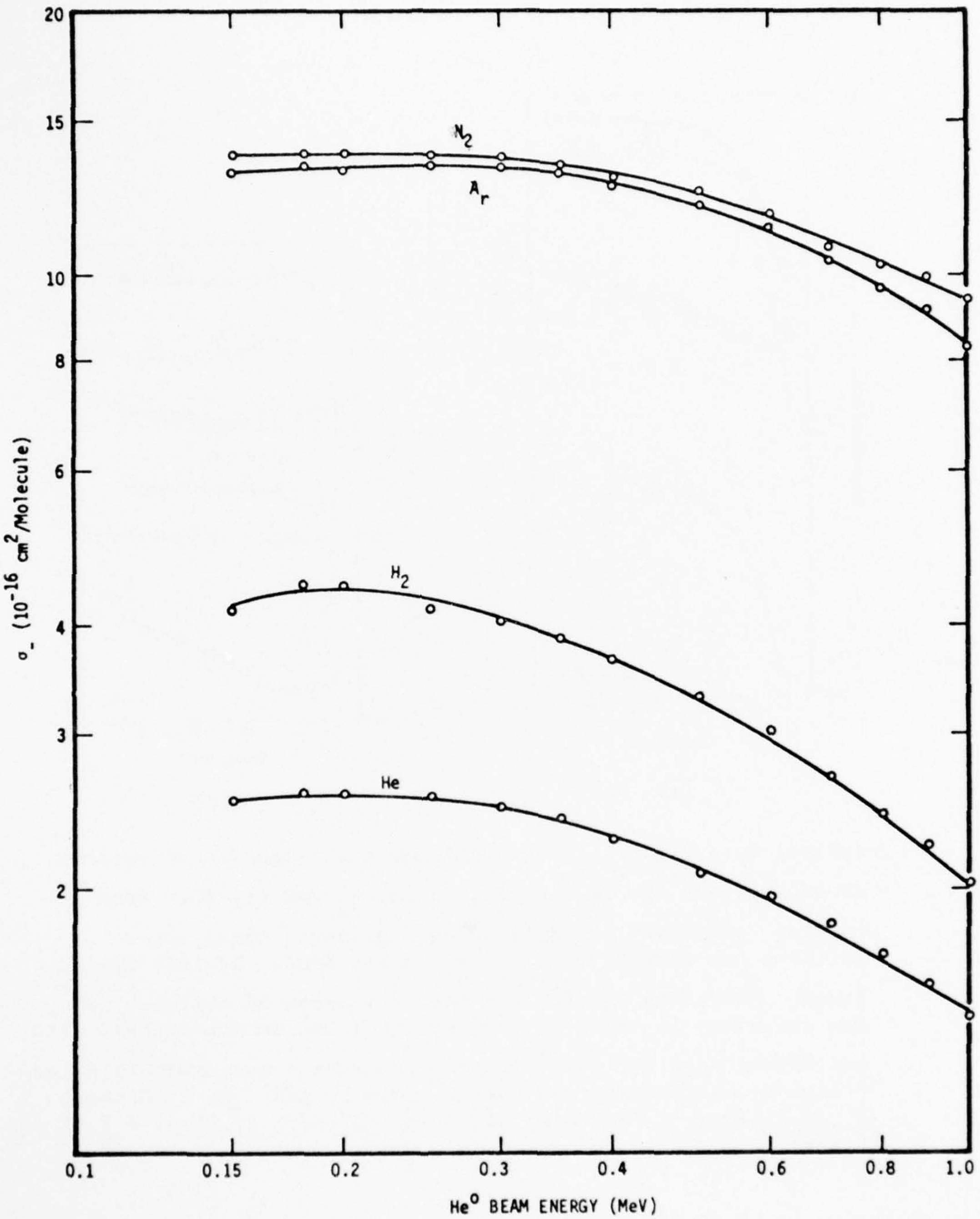


(a)

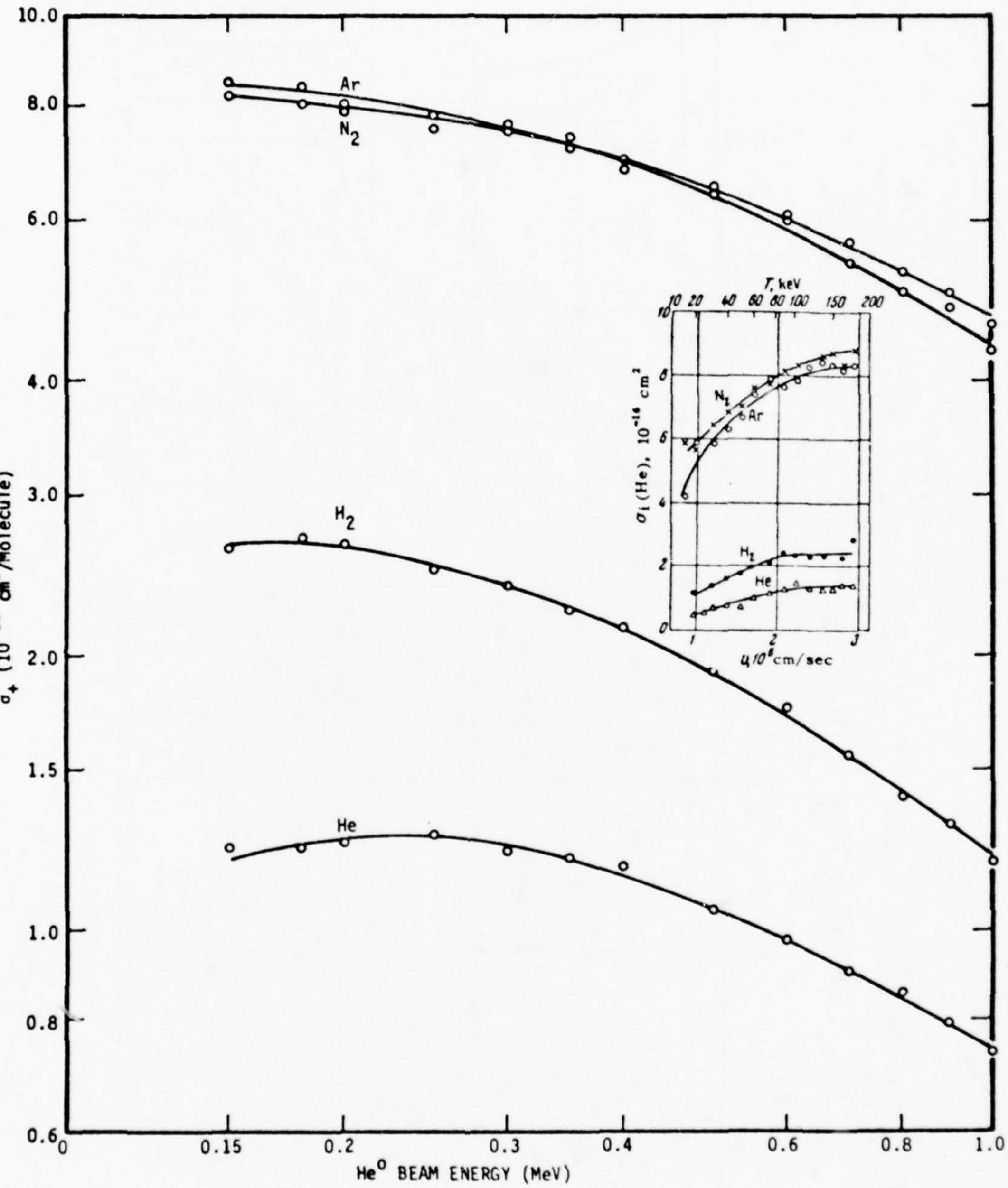


(b)

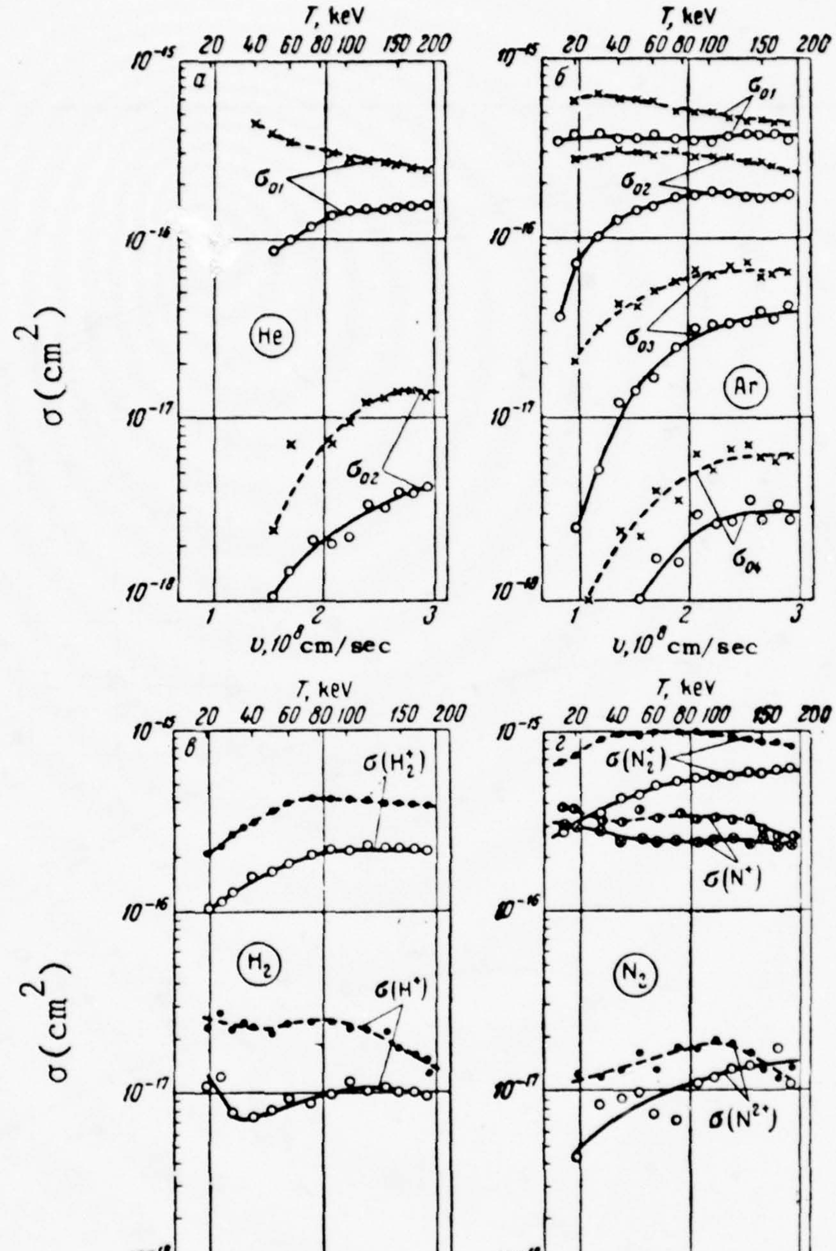
Graphical Data B-2.61. Cross sections for formation of various secondary ions by $^3He^{2+}$ impact on (a) H_2 and (b) CO. Open points: secondary ion data; closed points: total cross sections for formation of all secondary ions. Neglect dashed lines. Note data are for the mass 3 isotope of helium, $^3He^{2+}$, and are given in terms of this projectiles' impact energy. The equivalent data for $^4He^{2+}$ impact (the mass 4 isotope) can be generated by multiplying the energy scale by 4/3. W. G. Graham, C. J. Latimer, R. Browning and H. B. Gilbody, J. Phys. B 7, L 405 (1974).



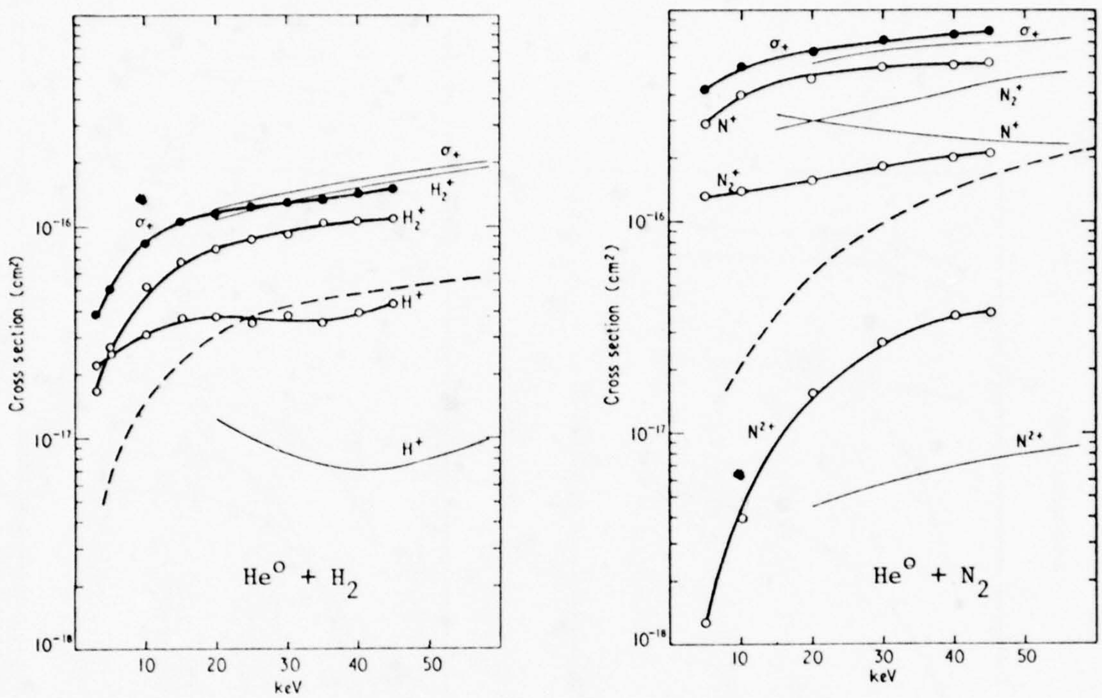
Graphical Data B-2.62. Cross sections for free electron production in He, Ar, H_2, N_2 targets by He° impact. L. J. Puckett et al., Phys. Rev. 178, 271 (1969). In addition to electrons formed by ionization of the target, this includes free electrons from stripping of the projectile.



Graphical Data B-2.63. Cross sections for slow positive ion production in He, Ar, H_2, N_2 by He° impact. Above 150 keV, data by L. J. Puckett et al., Phys. Rev. 178, 271 (1969); below 150 keV (shown as inset) due to E. S. Solovev et al., Soviet Physics JETP 18, 342 (1964).

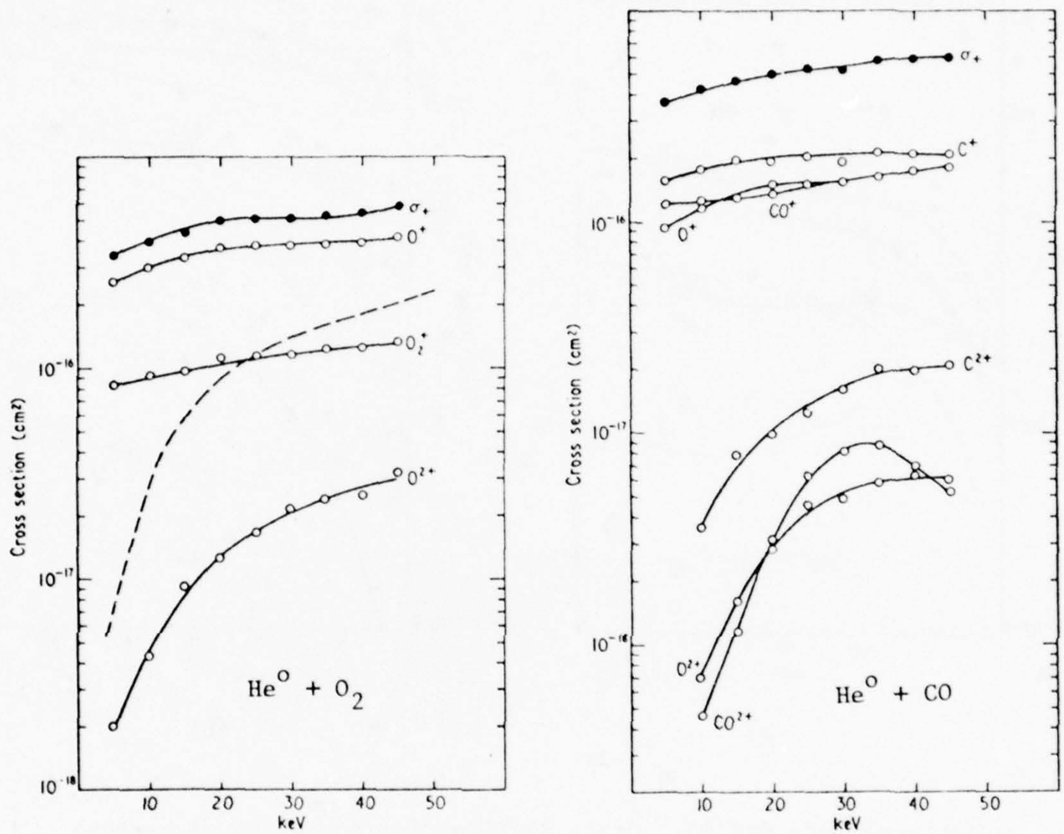


Graphical Data B-2.64. Cross section for forming various slow ions by He^+ (continuous curves) and He° (broken curves) impact on He, Ne, H_2, and N_2. σ_{oi} is the cross section for removing i electrons from a target atom. Data are shown as a function of incident velocity v and energy T. E. L. Solovev et al., Soviet Physics, JETP 18, 342 (1964).



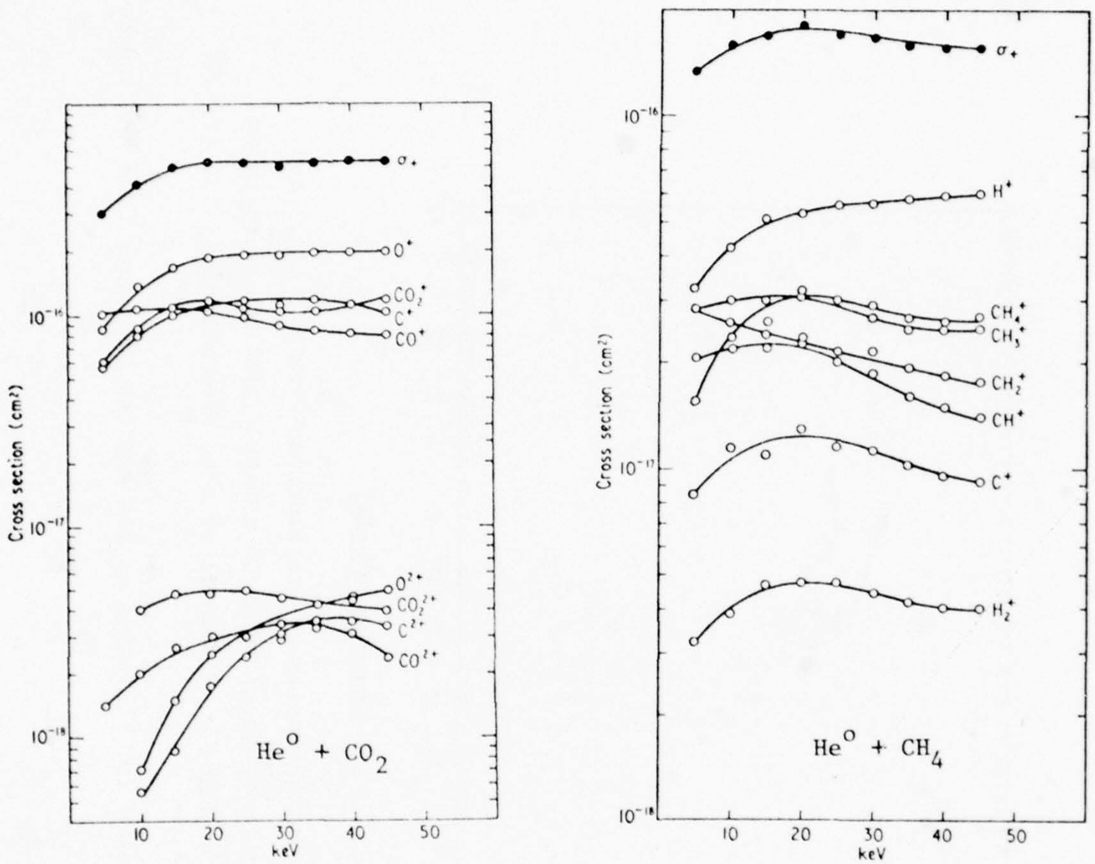
(a) (b)

Graphical Data B-2.65. Cross sections for formation of various secondary ions by He^{O} imapct on (a) H_2, (b) N_2. Open points, secondary ion data; closed points, total cross sections for formation of all secondary ions; neglect other curves.
R. Browning, C. J. Latimer and H. B. Gilbody, J. Phys. B 3, 667 (1970).



(a) (b)

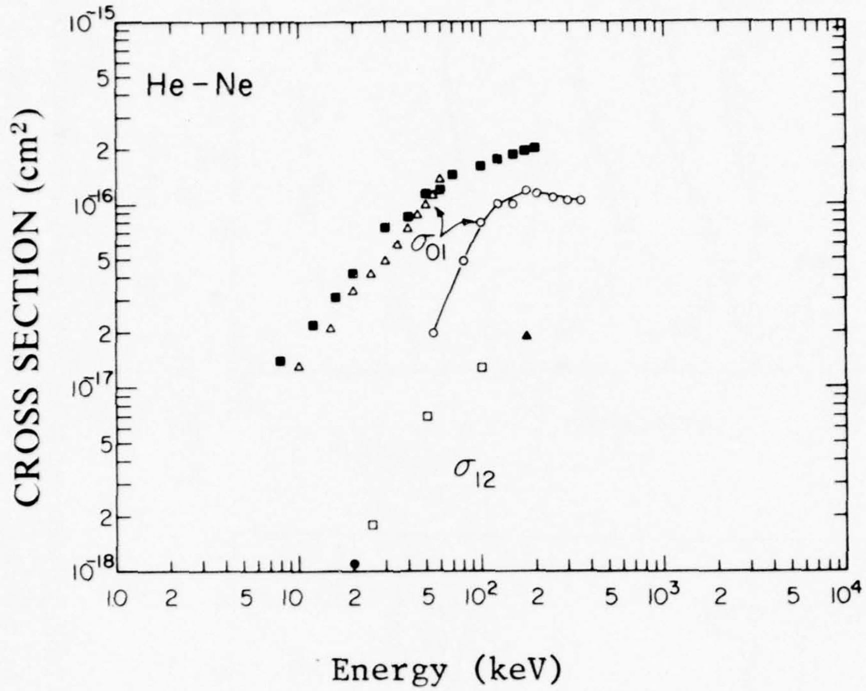
Graphical Data B-2.66. Cross sections for formation of various secondary ions by He^O impact on (a) O_2, (b) CO. Open points, secondary ion data; closed points, total cross section for formation of all secondary ions; neglect other curves. R. Browning, C. J. Latimer and H. B. Gilbody, J. Phys. B 2, 667 (1970).



(a) (b)

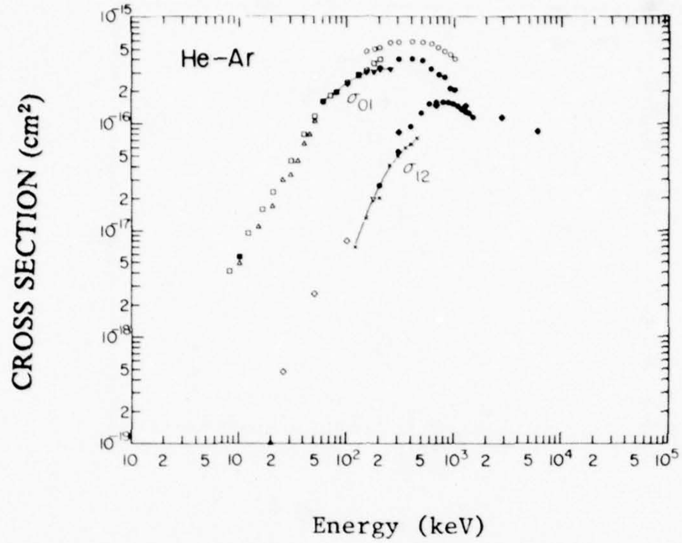
Graphical Data B-2.67. Cross sections for formation of various secondary ions by He^{O} impact on (a) CO_2 and (b) CH_4. Open points secondary ion data; closed points, total cross sections for formation of all secondary ions. R. Browning, C. J. Latimer and H. B. Gilbody, J. Phys. B 2, 667 (1970).

(a) For He^{o} and He^{+} in He, see Vol. I, pages 378, 379, 388 and 389.

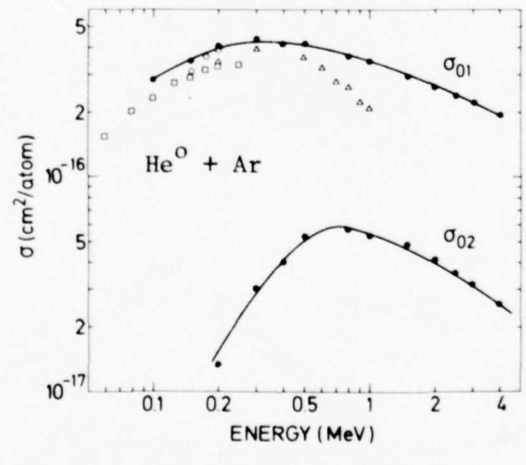


(b) Cross sections for stripping of one electron from He^{o} (σ_{01}) and one electron from He^{+} (σ_{12}) in an Ne target. The data were taken from the compendium by R. C. Dehmel et al., Atomic Data 5, 231 (1973).

Graphical Data B-2.68. Cross sections for stripping of one and two electrons from He^{o} and He^{+} traversing He and Ne.

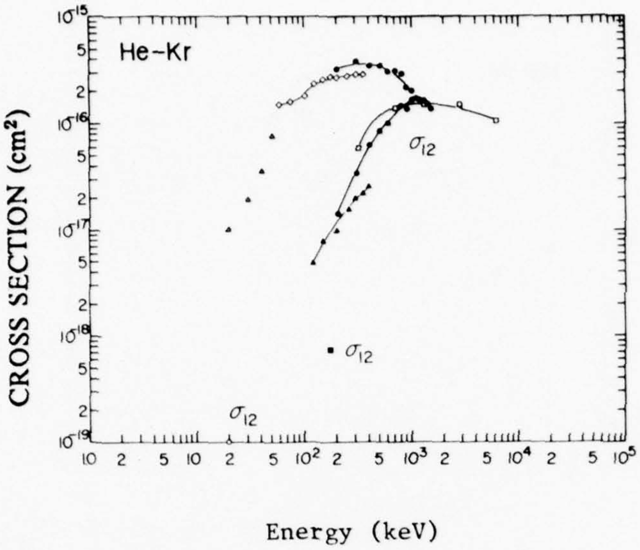


(a) Cross sections for stripping one electron from He^{o} (σ_{01}) and one electron from He^{+} (σ_{12}). The data were taken from the compendium by R. C. Dehmel et al., Atomic Data 5, 231 (1973).

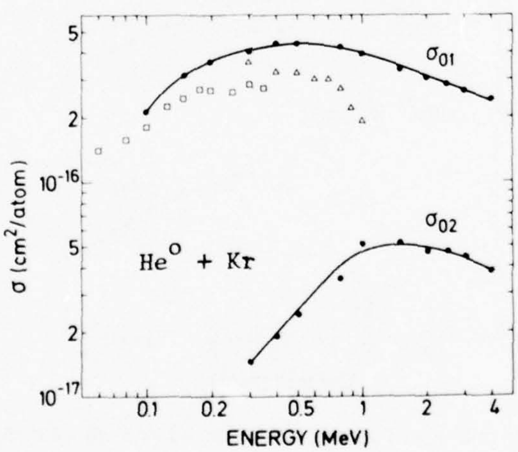


(b) Cross sections for stripping of one electron from He^{o} (σ_{01}) and two electrons from He^{o} (σ_{02}). The data were taken from P. Hvelplund and E. H. Pedersen, Phys. Rev. A 9, 2434 (1974).

Graphical data B-2.69. Cross sections for stripping of one and two electrons from He and He^{+} traversing Ar.

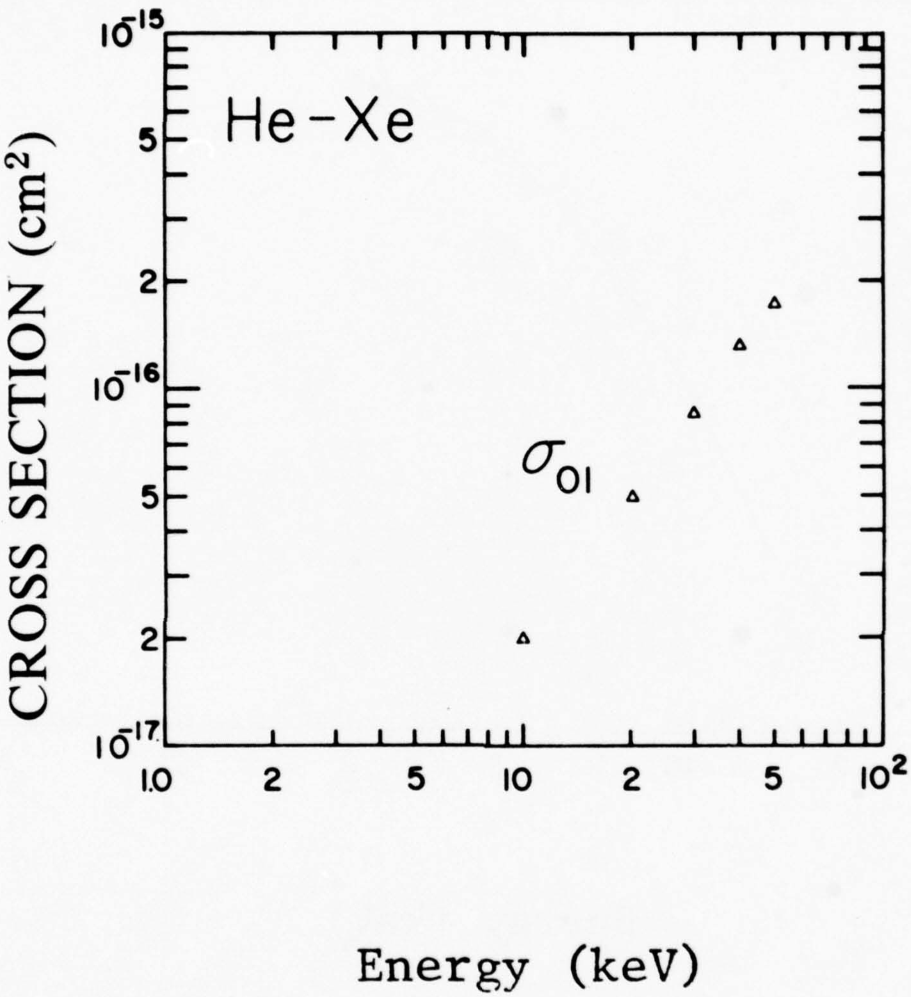


(a) Cross section for stripping one electron from He^{o} (σ_{01}, open triangles and two upper solid lines) and stripping one electron from He^{+} (σ_{12}). The data were taken from the compendium by R. C. Dehmel et al., Atomic Data 5, 231 (1973).



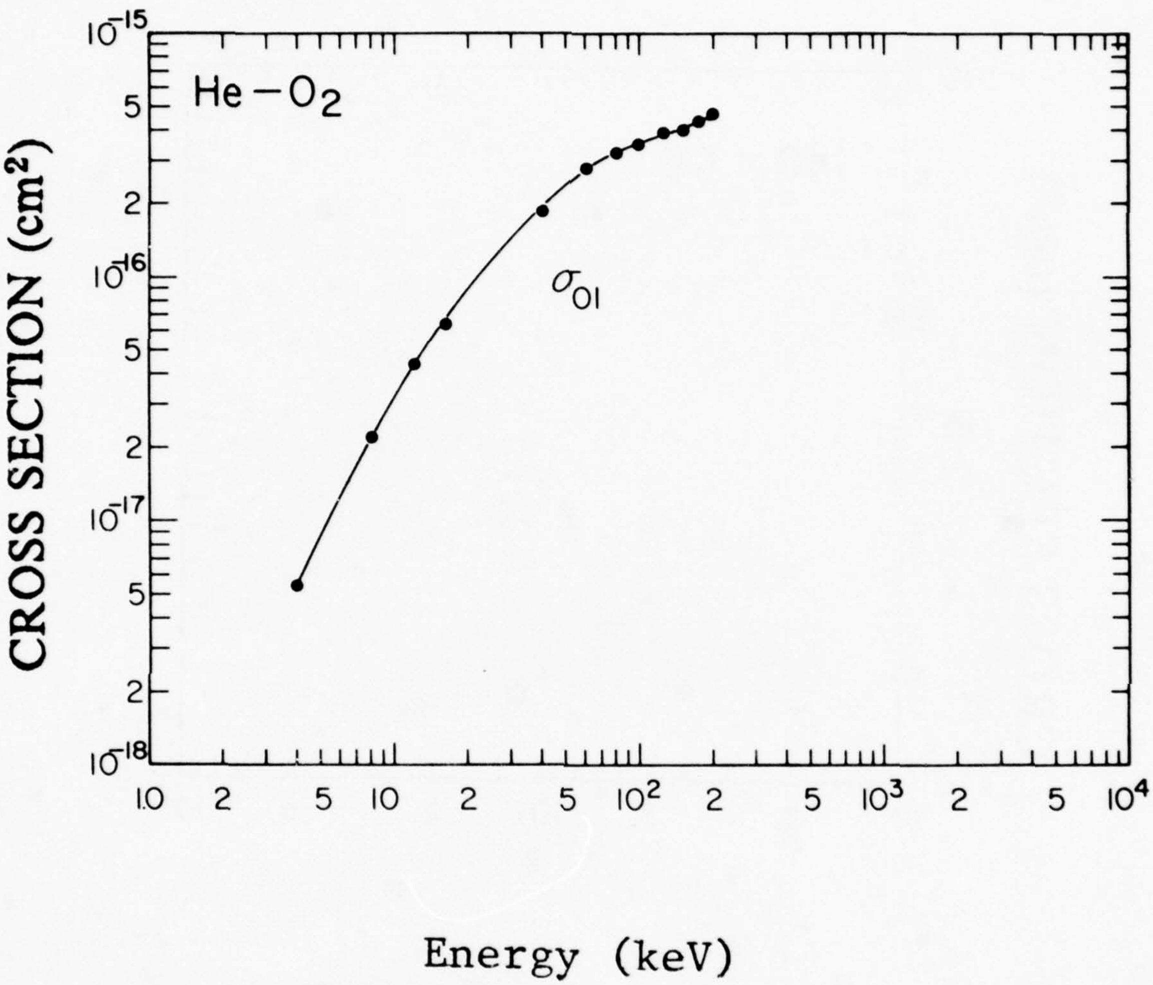
(b) Cross sections for stripping one electron from He^{o} (σ_{01}) and two electrons from He^{o} (σ_{02}). The data were taken from P. Hvelplund and E. H. Pedersen, Phys. Rev. A 9, 2434 (1974).

Graphical Data B-2.70. Cross sections for stripping of one and two electrons from He^{o} and He^{+} traversing Kr.



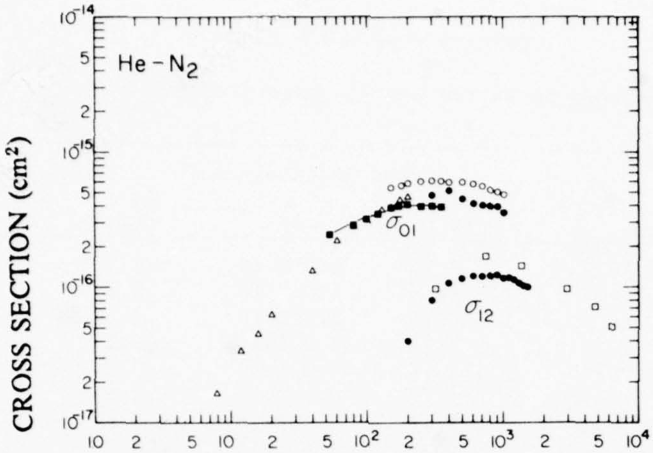
Graphical Data B-2.71. Cross sections for stripping of one electron from He^{o} traversing Xe. [From the compendium by R. C. Dehmel et al., Atomic Data 5, 231 (1973).]

(a) For He^{o} and He^{+} in H_2, see Vol. I, pages 378, 379, 388 and 389.

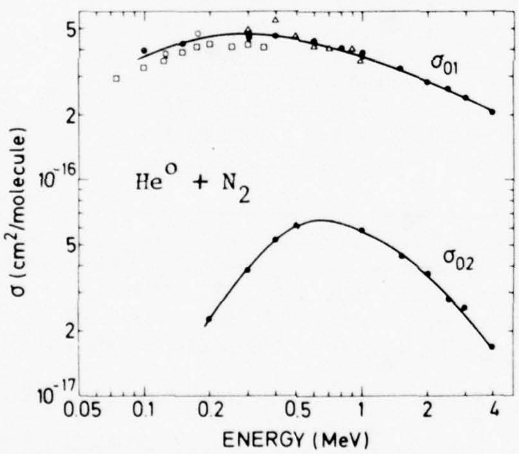


(b) Cross sections for stripping one electron from He^{o} as it traverses O_2. The data were taken from the compendium by R. C. Dehmel et al., Atomic Data 5, 231 (1973).

Graphical Data B-2.72. Cross sections for stripping of one and two electrons from He and He^{+} traversing H_2 and O_2.



(a) Cross sections for stripping one electron from He^o (σ_{01}) and one electron from He^+ (σ_{12}). The data were taken from the compendium by R. C. Dehmel et al., Atomic Data 5, 231 (1973).



(b) Cross sections for stripping one electron from He^o (σ_{01}) and two electrons from He^o (σ_{02}). The data were taken from P. Hvelplund and E. H. Pedersen, Phys. Rev. A 9, 2434 (1974).

Graphical Data B-2.73. Cross sections for stripping of one and two electrons from He^o and He^+ traversing N_2.

Tabular Data B-2.74. Electron capture by He^+ in He, Ne, Ar, Kr, and Xe.

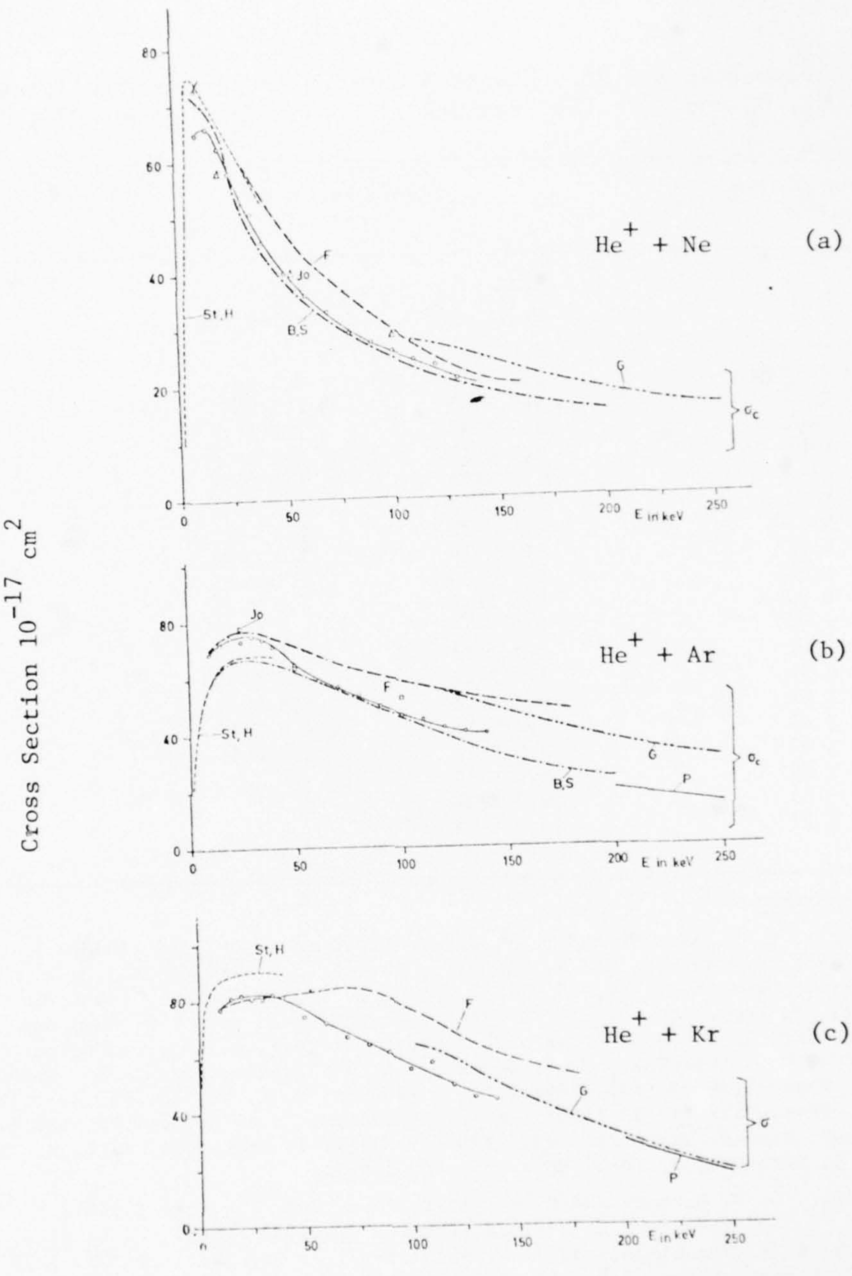
$$He^+ + X \rightarrow He + X^+$$

(For capture in He see Vol. I, page 374, 375)

Energy keV	Cross Section (cm^2) Ne	Ar	Kr	Xe
2.0 E-01	2.0 E-17	1.0 E-16	1.0 E-16	1.4 E-15
4.0 E-01	3.0 E-17	1.3 E-16	2.0 E-16	1.3 E-15
6.0 E-01	5.0 E-17	1.5 E-16	2.9 E-16	1.3 E-15
8.0 E-01	8.0 E-17	1.9 E-16	4.0 E-16	1.2 E-15
1.0 E00	1.1 E-16	2.1 E-16	5.0 E-16	1.2 E-15
2.0 E00	2.3 E-16	3.0 E-16	7.1 E-16	1.1 E-15
4.0 E00	5.8 E-16	4.2 E-16	8.5 E-16	1.3 E-15
6.0 E00	7.4 E-16	5.0 E-16	8.6 E-16	1.2 E-15
8.0 E00	7.3 E-16	5.1 E-16	8.7 E-16	1.1 E-15
1.0 E01	7.1 E-16	5.4 E-16	8.7 E-16	1.1 E-15
2.0 E01	6.5 E-16	7.5 E-16	9.0 E-16	1.1 E-15
4.0 E01	4.3 E-16	6.1 E-16	9.0 E-16	9.8 E-16
6.0 E01	3.5 E-16	6.0 E-16	8.5 E-16	1.1 E-15
8.0 E01	3.0 E-16	5.2 E-16	7.5 E-16	
1.0 E02	2.4 E-16	4.6 E-16	6.5 E-16	
2.0 E02	1.5 E-16	2.0 E-16	3.0 E-16	
4.0 E02	1.0 E-16	6.0 E-17	8.5 E-17	
6.0 E02		2.0 E-17	3.0 E-17	
8.0 E02		8.0 E-18	1.0 E-17	
1.0 E03		3.6 E-18	5.1 E-18	
1.4 E03		1.4 E-18	2.2 E-18	
1.5 E03		1.1 E-18	2.0 E-18	

References: J. B. A. Stedeford and J. B. Hasted, Proc. Roy. Soc. A227, 466 (1955). F. J. de Heer et al., Physica 32, 1793 (1966). C. F. Barnett and P. M. Stier, Phys. Rev. 109, 385 (1958).
H. B. Gilbody et al., Proc. Roy. Soc. A274, 40 (1973). Jones et al., Phys. Rev. 113, 182 (1959). Fedorenko et al., Soviet Physics JTP 1, 1861 (1956).
L. I. Pivovar et al., Soviet Physics JETP 15, 1035 (1962).

Notes: He^+ + Ne The tabular data are basically those of Stedeford and Hasted, Barnett and Stier, and of Gilbody et al.
He^+ + Ar The tabular data are basically those of Stedeford and Hasted, Barnett and Stier, and of Pivovar et al.
He^+ + Kr The tabular data are basically those of Stedeford and Hasted, Gilbody et al. and of Pivovar et al.



Graphical Data B-2.75. Cross sections for single electron capture by He^+ in (a) Ne, (b) Ar, (c) Kr. Partial representations of available data only; it is recommended that the tabular data on the preceding page be utilized.

Tabular Data B-2.76. Electron capture cross sections for He^+ in H_2, O_2 and N_2. (For capture in H_2 see Vol I pages 374, 375).

Energy (keV)	Cross Sections (cm^2)	
	σ_{10} $He^+ + N_2 \rightarrow He^\circ$	σ_{10} $He^+ + O_2 \rightarrow He^\circ$
1.0 E-03	6.0 E-15	
2.0 E-03	5.2 E-15	3.0 E-15
5.0 E-03	4.0 E-15	2.7 E-15
1.0 E-02	3.0 E-15	2.2 E-15
2.0 E-02	2.1 E-15	1.8 E-15
5.0 E-02	1.4 E-15	1.4 E-15
1.0 E-01	1.2 E-15	1.3 E-15
2.0 E-01	1.1 E-15	1.3 E-15
5.0 E-01	9.7 E-16	1.2 E-15
1.0 E 00	9.2 E-16	1.1 E-15
2.0 E 00	8.6 E-16	1.0 E-15
5.0 E 00	8.0 E-16	9.4 E-16
1.0 E 01	7.5 E-16	8.6 E-16
2.0 E 01	7.0 E-16	7.7 E-16
5.0 E 01	6.2 E-16	6.5 E-16
1.0 E 02	4.7 E-16	4.8 E-16
2.0 E 02	2.5 E-16	3.0 E-16
5.0 E 02	6.0 E-17	
1.0 E 03	9.2 E-18	
1.5 E 03	2.5 E-18	

References:

$He^+ + N_2$: C. F. Barnett and P. M. Stier, Phys. Rev. 109, 385 (1958); F. J. De Heer, J. Schutten, and H. Moustafa, Physica 32, 1793 (1966); D. W. Koopman, Phys. Rev. 166, 57 (1968); R. C. C. Lao, R. Rozett, and W. S. Koski, J. Chem. Phys. 49, 4202 (1968); P. Mahadevan and C. D. Magnuson, Fifth Int. Conf. on Electron and Atomic Collisions, p. 405, Leningrad (1967); V. S. Nikolaev, I. S. Dmitriev, L. N. Fateeva, and Ya. A. Teplova, Sov. Phys.-JETP 13, 695 (1961); L. I. Pivovar, V. M. Tubaev, and M. T. Novikov, Sov. Phys.-JETP 14, 20 (1962); R. F. Stebbings, J. A. Rutherford, and B. R. Turner, Planet. Space Sci. 13, 1125 (1965); R. F. Stebbings, A. C. H. Smith, and E. Ehrhardt, J. Chem. Phys. 39, 968 (1963).

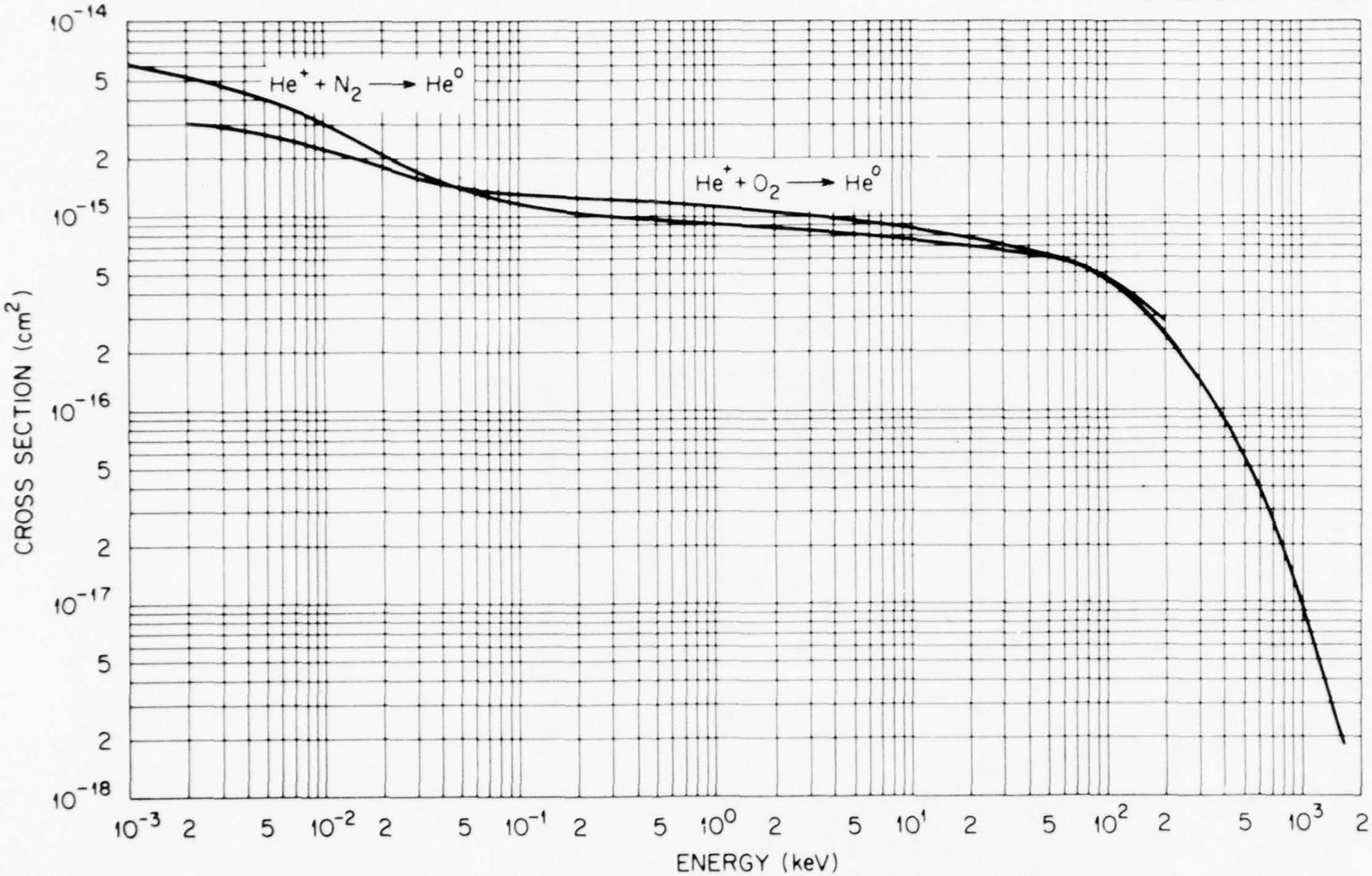
$He^+ + O_2$: C. F. Barnett and P. M. Stier, Phys. Rev. 109, 385 (1958); F. J. De Heer, J. Schutten, and H. Mostafa, Physica 32, 1793 (1966); W. L. Fite, A. C. H. Smith, R. F. Stebbings, and J. L. Rutherford, J. Geophys. Res. 68, 3225 (1963); D. W. Koopman, Phys. Rev. 166, 57 (1968); P. Mahadevan and G.D. Magnuson, Fifth Int. Conf. on Electron and Atomic Collisions, p. 405, Leningrad (1967); P. Mahadevan and C. D. Magnuson, Phys. Rev. 171, 103 (1968); R. F. Stebbings, A. C. H. Smith and E. Ehrhardt, J. Chem. Phys. 39, 968 (1963).

Accuracy:

$He^+ + N_2$: $\pm$ 25%.

$He^+ + O_2$: $\pm$ 25%.

ORNL-DWG 76-6763



Graphical Data B-2.77. Cross sections for capture of one electron by He^+ impact on N_2 and O_2. Tabular data on preceding page.

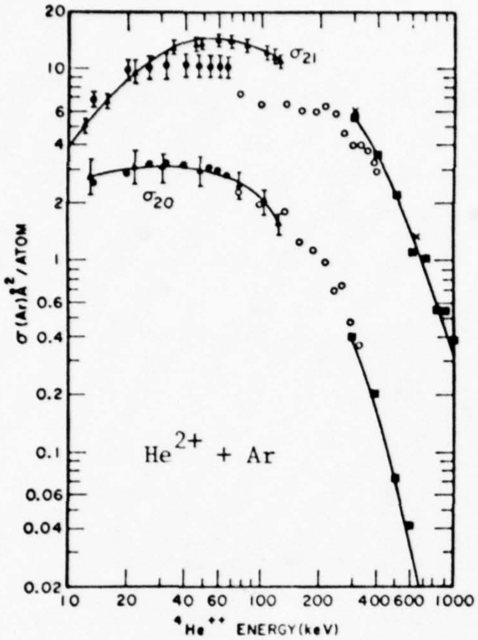
Tabular Data B-2.78. Electron capture cross sections for He^+ in CO_2 and H_2O.

(Fragmentary Data)

$$He^+ + X \rightarrow He + X^+$$

Energy keV	Cross Section (cm^2) CO_2	H_2O
1.0 E-01	1.1 E-15	1.2 E-16
2.0 E-01	1.0 E-15	9.0 E-17
4.0 E-01	9.0 E-16	8.5 E-17
6.0 E-01	8.5 E-16	8.0 E-17
8.0 E-01	8.0 E-16	7.5 E-17
1.0 E00	7.9 E-16	7.0 E-17
1.4 E00	7.6 E-16	6.8 E-17

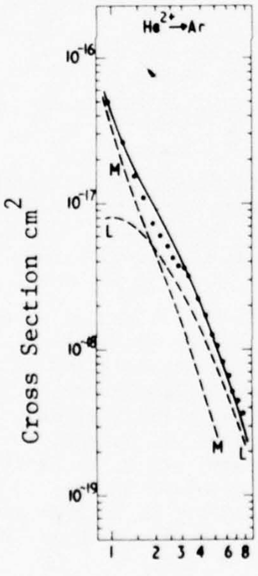
Reference: D. W. Koopman, Phys. Rev. 166, 57 (1968).



$He^{2+} + Ar \rightarrow He^{+} + Ar^{+} \quad \sigma_{21}$

$He^{2+} + Ar \rightarrow He^{o} + Ar^{2+} \quad \sigma_{20}$

(a) Compendium of data for σ_{21} and σ_{20} drawn from the work of J. E. Bayfield and G. A. Khayrallah, Phys. Rev. A 11, 920 (1975).



$He^{2+} + Ar \rightarrow He^{+} + Ar^{+} \quad \sigma_{21}$

$He^{2+} + Ar \rightarrow He^{o} + Ar^{2+} \quad \sigma_{20}$

(b) High energy data for σ_{21} from the work of P. Hvelplund et al., J. Phys. B 9, 491 (1976). The data are shown as points; all the curves relate to theoretical estimates and may be ignored.

Graphical Data B-2.79. Electron capture cross sections for He^{2+} in Ar.

Tabular Data B-2.80. Electron capture cross sections for He^{++} in H and H_2.

Energy (keV)	Cross Sections (cm^2)		
	σ_{21} $He^{++}+H \rightarrow He^{+}$	σ_{21} $He^{++}+H_2 \rightarrow He^{+}$	σ_{20} $He^{++}+H_2 \rightarrow He^{o}$
5.3 E-01		3.8 E-17	
8.0 E-01		7.8 E-17	
1.3 E 00		1.0 E-16	
2.7 E 00	8.4 E-17	1.3 E-16	
5.3 E 00	3.6 E-16	1.7 E-16	
6.0 E 00	4.2 E-16	1.8 E-16	
8.0 E 00	5.9 E-16	1.9 E-16	1.1 E-17
1.0 E 01	7.0 E-16	2.5 E-16	1.1 E-17
2.0 E 01	1.1 E-15	4.8 E-16	1.9 E-17
5.0 E 01	1.2 E-15	9.4 E-16	5.1 E-17
7.5 E 01	1.1 E-15	9.7 E-16	5.6 E-17
1.0 E 02	9.8 E-16	9.2 E-16	6.0 E-17
2.0 E 02	2.9 E-16	4.7 E-16	4.0 E-17
5.0 E 02	1.8 E-17	8.0 E-17	2.2 E-18
7.5 E 02		1.5 E-17	4.8 E-19
1.0 E 03		5.2 E-18	1.6 E-19
1.4 E 03		1.3 E-18	4.7 E-20
2.0 E 03		3.0 E-19	
3.0 E 03		4.4 E-20	
3.8 E 03		1.8 E-20	

References:

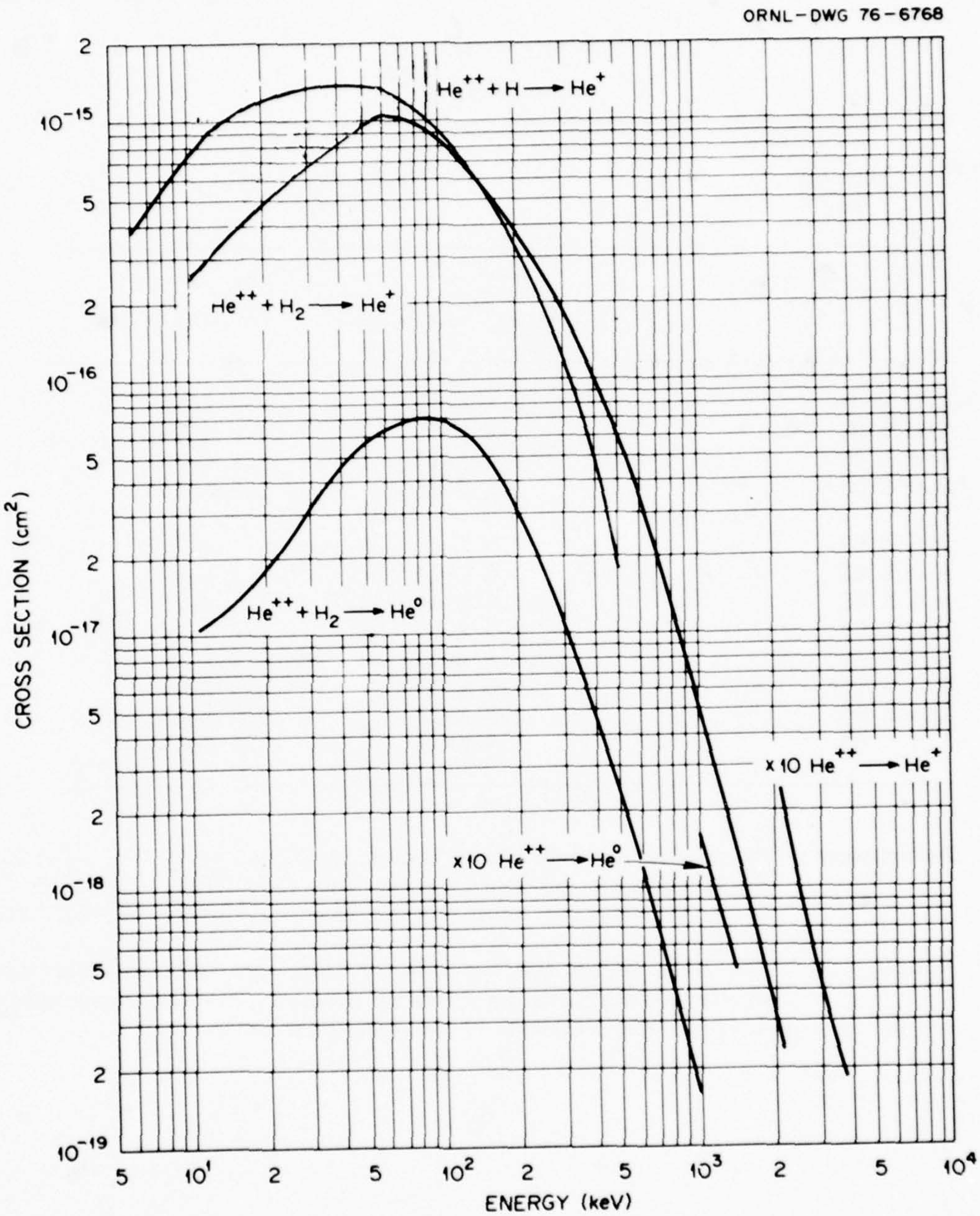
$He^{++}+H \rightarrow He^{+}$: W. L. Fite, A. C. H. Smith, and R. F. Stebbings, Proc. Roy. Soc. London A268, 527 (1962); J. E. Bayfield and G. A. Khayrallah, Phys. Rev. A 12, 869 (1975); M. B. Shah and H. B. Gilbody, J. Phys. B7, 630 (1974). W. L. Nutt et al., J. Phys. B11, 1457 (1978); M. B. Shah and H. B. Gilbody, J. Phys. B11, 121 (1978).

$He^{++}+H_2$: S. K. Allison, Phys. Rev. 109, 76 (1958); S. K. Allison, J. Cuevas, and P. G. Murphy, Phys. Rev. 102, 1041 (1956); R. A. Baragiola and I. B. Nemirovsky, Nucl. Inst. and Meth. 110, 511 (1973); J. E. Bayfield and G. A. Khayrallah, Phys. Rev. A 11, 920 (1975); P. Hvelplund, J. Heinemeier, E. H. Pedersen and F. R. Simpson, 9th Int. Conf. Atomc. & Elect. Coll. p. 185, Seattle, Wash. (1975); L. I. Pivovar, M. T. Novikov and V. M. Tubaev, Sov. Phys.- JETP 15, 1035 (1962); L. I. Pivovar, V. M. Tubaev, and M. T. Novikov, Sov. Phys.- JETP 14, 20 (1962); M. B. Shah and H. B. Gilbody, J. Phys. B 7, 256 (1974). W. L. Nutt et al., J. Phys. B 11, 1457 (1978); M. B. Shah and H. B. Gilbody, J. Phys. B 11, 121 (1978); P. Hvelplund et al., J. Phys. B 9, 491 (1976).

Accuracy:

$He^{++}+H$: $\pm$ 40%.

$He^{++}+H_2$: $\pm$ 40%.



Graphical Data B-2.81. Electron capture cross sections for He^{++} in H and H_2. (Tabular data are presented on the preceding page.)

Tabular Data B-2.82. Electron capture cross sections for He^{2+} in Kr.

$$He^{2+} + Kr \rightarrow He^{+} + Kr^{+}$$
$$\rightarrow He + Kr^{2+}$$

Energy keV	Cross Section cm^2	
	σ_{21} $He^{2+} + Kr \rightarrow He^{+}$	σ_{20} $He^{2+} + Kr \rightarrow He^{o}$
2.0 E 01	1.9 E-15	4.3 E-16
4.0 E 01	1.9 E-15	4.2 E-16
6.0 E 01	1.8 E-15	3.9 E-16
8.0 E 01	1.6 E-15	3.6 E-16
2.0 E 02	7.0 E-16	
4.0 E 02	3.8 E-16	2.3 E-17
6.0 E 02	1.4 E-16	4.1 E-18
8.0 E 02	7.5 E-17	1.4 E-18
1.0 E 03	4.5 E-17	8.0 E-19
1.2 E 03	3.0 E-17	6.0 E-19
1.4 E 03	2.0 E-17	5.8 E-19
1.5 E 03	1.9 E-17	5.0 E-19

References: M. B. Shah and H. B. Gilbody, J. Phys. B 7, 256 (1974);
L. I. Pivovar et al., Soviet Physics, JETP, 15, 1035 (1962).
L. I. Pivovar et al., Soviet Physics, JETP, 14, 20 (1962).

Note: The data below 100 keV are by Shah and Gilbody, the data above 100 keV are by Pivovar et al. One may reasonably interpolate between these two data sets.

Tabular Data B-2.83. Electron capture cross sections for He^{++} in N_2, H_2, and O_2. (For H_2 target see Vol. I, pages 376 and 377.)

Energy (keV)	Cross Sections (cm^2)			
	σ_{21} $He^{++}+N_2 \to He^+$	σ_{20} $He^{++}+N_2 \to He^\circ$	σ_{21} $^3He^{++}+O_2 \to He^+$	σ_{20} $^3He^{++}+O_2 \to He^\circ$
1.0 E 01	5.6 E-16	2.5 E-16	5.6 E-16	3.6 E-16
2.0 E 01	8.9 E-16	3.1 E-16	8.1 E-16	3.8 E-16
3.0 E 01	1.1 E-15	3.3 E-16	8.4 E-16	3.7 E-16
5.0 E 01	1.2 E-15	3.3 E-16	8.5 E-16	3.2 E-16
7.0 E 01	1.2 E-15	3.1 E-16		
1.0 E 02	1.1 E-15	2.6 E-16		
2.0 E 02	6.1 E-16	1.0 E-16		
4.0 E 02	2.0 E-16	1.2 E-17		
7.0 E 02	7.3 E-17	2.0 E-18		
1.0 E 03	3.4 E-17	6.0 E-19		
1.5 E 03	7.7 E-18	1.4 E-19		

References:

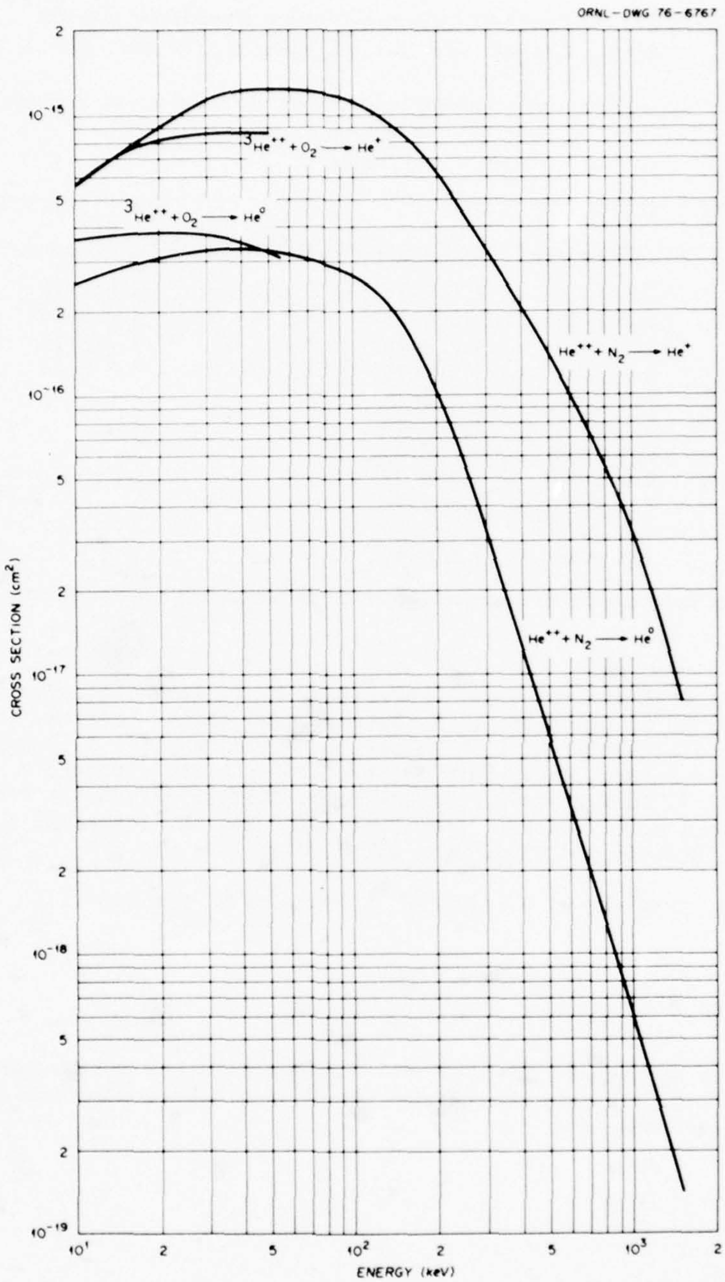
$He^{++}+N_2$: J. E. Bayfield and G. A. Khayrallah, Phys. Rev. A 11, 920 (1975); V. S. Nikolaev, I. S. Dmitriev, L. N. Fateeva, and Ya. A. Teplova, Sov. Phys.-JETP 13, 695 (1961); V. S. Nikolaev, L. N. Fateeva, I. S. Dmitriev, and Ya. A. Teplova, Sov. Phys.-JETP 14, 67 (1962); L. I. Pivovar, M. T. Novikov, and V. M. Tubaev, Sov. Phys.-JETP 15, 1035 (1962); L. I. Pivovar, V. M. Tubaev, and M. T. Novikov, Sov. Phys.-JETP 14, 20 (1962); M. B. Shah and H. B. Gilbody, J. Phys. B 7, 256 (1974).

$He^{++}+O_2$: M. B. Shah and H. B. Gilbody, J. Phys. B 7, 256 (1974).

Accuracy:

$He^{++}+N_2$ - ± 20%. $He^{++}+O_2$ - ± 20%.

Note: Data for N_2 targets are with $^4He^{2+}$ projectiles and for O_2 targets with $^3He^{2+}$ projectiles. It is expected that $^3He^{2+}$ will behave identically with $^4He^{2+}$ at the same velocity.



Graphical Data B-2.84. Cross sections for one and two electron capture for He^{++} in N_2 and O_2. (See the tabular data on the preceeding page and the note concerning the isotope of He^{++} utilized.)

Data Source Listing B-2.85. Excitation of noble gases by helium impact.

Excitation of the noble gases (He, Ne, Ar, Kr, and Xe) has been adequately covered in Vol. I of this report and no further data will be reproduced here. Measurements are confined to impact energies below 100 keV and are entirely for He^{+} projectiles; there is no information for He^{o} and He^{++} impact. Page references in Volume I are as follows:

$He^{+} + He \rightarrow He^{+} + He^{*}$ (4^3S, 4^3P, 4^3D)	Pages 372 and 373
$He^{+} + Ne \rightarrow Ne^{*}$	Page 426
$He^{+} + Ar \rightarrow Ar^{*}$	Pages 421 and 426
$He^{+} + Kr \rightarrow He^{*}$	Page 416
$He^{+} + Kr \rightarrow Kr^{*}, Kr^{+*}$	Pages 421, 422, 424, and 426
$He^{+} + Xe \rightarrow He^{*}$	Page 416
$He^{+} + Xe \rightarrow Xe^{*}, Xe^{+*}$	Pages 421, 423, 424, and 426

These pages give a representative selection of data for a variety of excited states. Substantial additional information covering additional energy levels is to be found in the compendium by Thomas ("Excitation in Heavy Particle Collisions", Wiley, 1972). One should also note limited additional studies on the $He^{+} + Ar \rightarrow Ar^{+*}$ reaction at energies up to 10 keV by Lipeless et al., Phys. Rev. Letters 24, 799 (1970) and Phys. Rev. A 4, 140 (1971), and by Isler, Phys. Rev. A 10, 117 (1974).

Data Source Listing B-2.86. Excitation of molecular gases by helium impact.

Excitation of molecular gases by helium impact has been covered only in a fragmentary fashion. The situation is as follows:

- H_2 Target - Excitation of H_2 by He^+ and He^o has been studied from 5 to 30 keV and is reproduced here in Tables and Figures B-2.87 through B-2.91.

- N_2 Target - Excitation of one level in N_2^+ by He^+ impact has been studied and is reproduced as Graphical Data B-2.92. There are also studies of the relative population of rotational levels in the excited N_2^+ ($B\ ^2\Sigma_u^+$) state induced by He^+ and He impact. These are not reproduced here and the reader is referred to the following publications:

  Polyakova et al., Soviet Physics JETP 25, 430 (1967).

  Polyakova et al., Soviet Physics JETP 27, 201 (1968).

  Polyakova et al., Soviet Physics JETP 30, 63 (1970).

  Sheridan and Clark, Phys. Rev. 140, A1033 (1965).

  Moore and Doering, Phys. Rev. 182, (1969).

- O_2 Target - No published information.

- CO Target - Very limited study on formation of excited carbon; M. Lipeless, Physics Letters 29A, 297 (1969). No cross section information.

- CO_2 Target - Some studies of relative spectral line intensities but no cross section data; M. J. Haugh and J. H. Birely, J. Chem. Phys. 60, 264 (1974).

- Other Molecular Targets - No published information.

Tabular Data B-2.87. Cross sections for formation of excited H by He^+ impact on H_2 and on H.

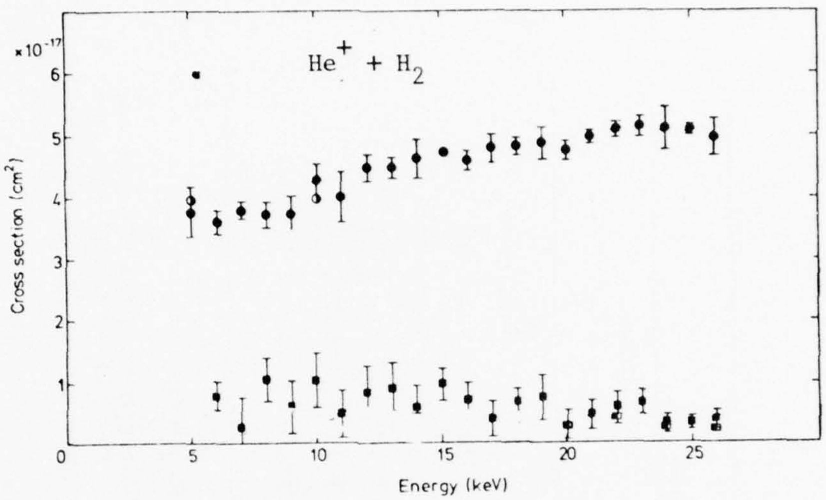
$$He^+ + H_2 \rightarrow He^+ + H^*(n,\ell) + H$$

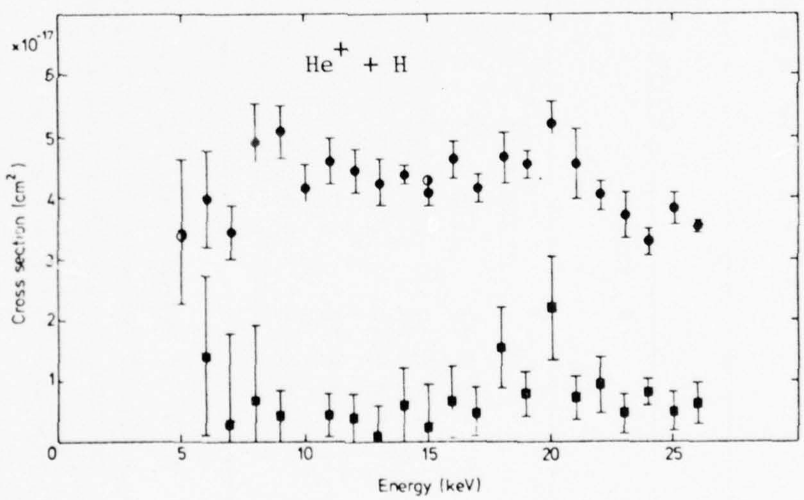
$$He^+ + H \rightarrow He^+ + H^*(n,\ell)$$

Energy keV	Cross Section (cm^2) H_2 target 2s	H_2 target 2p	H target 2s	H target 2p
5.0 E 00		3.8 E-17		3.4 E-17
7.0 E 00	2.6 E-18	3.8 E-17	2.6 E-18	3.4 E-17
1.0 E 01	1.0 E-17	4.3 E-17		4.1 E-17
1.5 E 01	9.8 E-18	4.8 E-17	2.2 E-18	4.1 E-17
2.0 E 01	3.1 E-18	4.8 E-17	2.2 E-17	5.2 E-17
2.6 E 01	4.0 E-18	5.0 E-17	6.0 E-18	3.5 E-17

Reference: J. D. A. McKee et al., J. Phys. B 10, 1679 (1977).

Accuracy: Authors' estimates of reliability indicate large uncertainties in the 2s data; as much as ± 100% in some cases. For the 2p level the estimated reliability is about ± 5%. Data are reproduced on the following page and includes error bars.





Graphical Data B-2.88. Cross sections for formation of H(2s) (squares) and H(2p) (circles) by He^+ impact on H_2 (upper graph) and on H (lower graph). The data were taken from J. D. A. McKee et al., J. Phys. B 10, 1679 (1977).

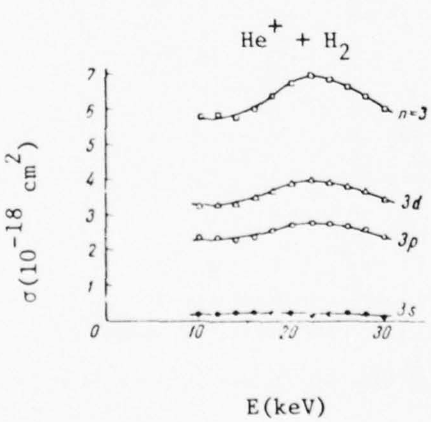
Tabular Data B-2.89. Cross sections for formation of excited H by He^+ impact on H_2.

$$He^+ + H_2 \rightarrow He^+ + H^*(n\ell) + H^+$$

Energy keV	Cross Section (cm^2)			
	3s	3p	3d	n=3
1.00 E 01	2.17 E-19	2.36 E-18	3.25 E-18	5.78 E-18
1.20 E 01	2.24 E-19	2.36 E-18	3.26 E-18	5.83 E-18
1.40 E 01	2.31 E-19	2.30 E-18	3.29 E-18	5.76 E-18
1.60 E 01	2.45 E-19	2.36 E-18	3.47 E-18	6.00 E-18
1.80 E 01	2.38 E-19	2.56 E-18	3.65 E-18	6.38 E-18
2.00 E 01	2.38 E-19	2.71 E-18	3.85 E-18	6.75 E-18
2.20 E 01	1.75 E-19	2.78 E-18	3.98 E-18	6.97 E-18
2.40 E 01	2.17 E-19	2.75 E-18	3.88 E-18	6.84 E-18
2.60 E 01	2.59 E-19	2.66 E-18	3.78 E-18	6.63 E-18
2.80 E 01	2.17 E-19	2.58 E-18	3.65 E-18	6.38 E-18
3.00 E 01	1.33 E-19	2.37 E-18	3.42 E-18	6.00 E-18

Reference: V. A. Ankudinov, S. V. Bobashev and E. P. Andreev, Soviet Physics JETP 25, 236 (1967).

Note: The data shown under n=3 is the sum of cross sections for the 3s, 3p and 3d states representing the cross section for formation of H in the n=3 state.

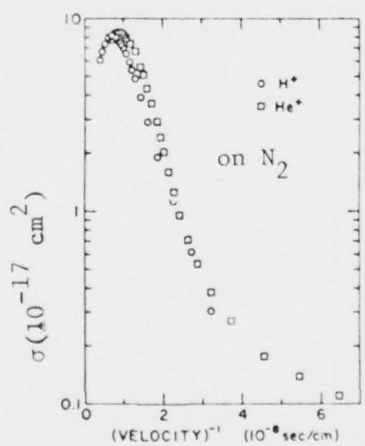


Graphical Data B-2.90. Cross sections for formation of H in the 3s, 3p, and 3d excited states by H^+ impact on H_2 and also the sum of these three cross sections. (The data were taken from the preceeding table.)

Tabular Data B-2.91. Emission of the Balmer α and β lines of H Induced by He^+ and He^0 impact on H_2. [These data are cross sections for emission of the Balmer α (6563 Å) and β (4861 Å) spectral lines.]

Energy keV	Cross Section (cm^2) He+ Impact H_α	H_β	He° Impact H_α	H_β
1.0 E-01	4.6 E-18	5.7 E-19		
2.0 E-01	7.3 E-18	9.0 E-19		
6.6 E-01	3.6 E-18	8.2 E-19	6.4 E-19	1.7 E-19
1.0 E 00	2.6 E-18	5.1 E-19	8.8 E-19	2.7 E-19
2.0 E 00	2.1 E-18	4.0 E-19	1.1 E-18	4.4 E-19
5.0 E 00	2.0 E-18	3.9 E-19	1.6 E-18	5.4 E-19
7.0 E 00	2.1 E-18	3.8 E-19	1.8 E-18	5.6 E-19
1.0 E 01	2.3 E-18	4.2 E-19	1.9 E-18	5.5 E-19
2.0 E 01	3.1 E-18	5.7 E-19	1.7 E-18	4.6 E-19
3.0 E 01	3.5 E-18	4.9 E-19	1.6 E-18	4.0 E-19

Reference: V. A. Gusev, G. N. Polyakova, V. F. Erko, Ya. M. Fogel, and A. V. Zats. Abstracts of the "Sixth International Conference on the Physics of Electronic and Atomic Collisions", MIT Press, Cambridge, Massachusetts., 809 (1969).

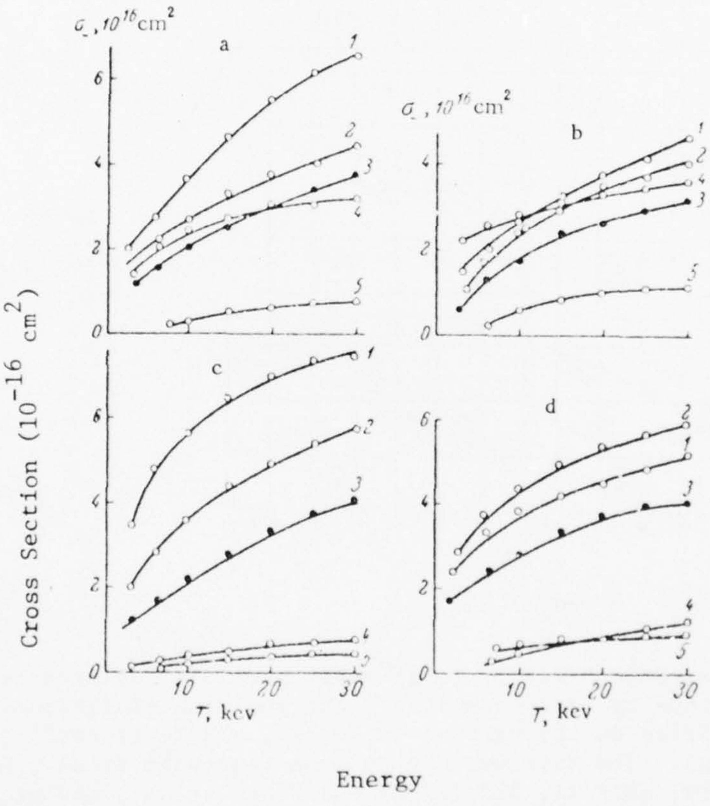


Graphical Data B-2.92. Cross sections for excitation of the N_2^+ 3914 Å ($B\ ^2\Sigma_u^+ \rightarrow X^2\Sigma_g^+$ (0,0)) transition by He^+ impact on N_2. The data are shown as a function of projectile velocity (corresponding to 0.5 to 34 keV energy) and compared with equivelocity protons. The data were taken from P. J. Wehrenberg, Phys. Rev. A 15, 843 (1977).

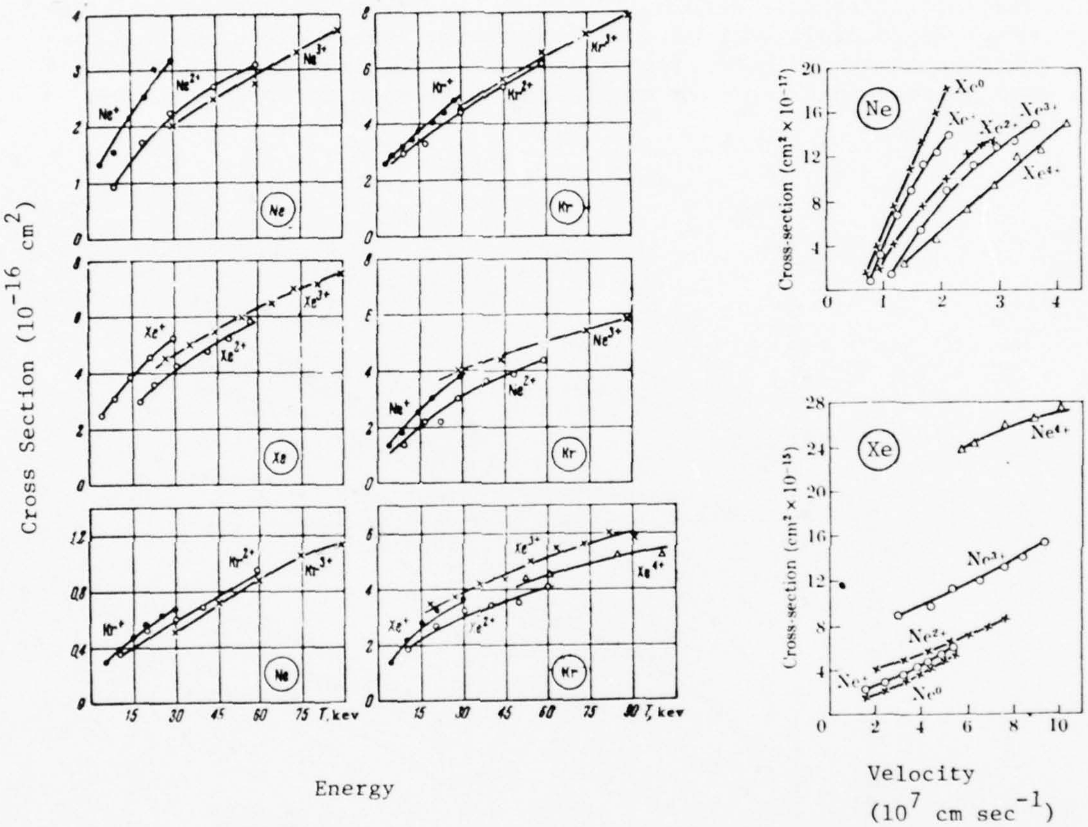
Slow Electron Production by Impact of Heavy Ions and Atoms

Introduction

The slow electrons produced by impact of a heavy ion on a target arise from ionization of the target and also by ionization of the projectile (stripping); data on this total electron production are given here. Regrettably the data are fragmentary and by no means have the scope required for modelling of nuclear pumped lasers; however they do seem to represent the only significant data sets in the published literature.

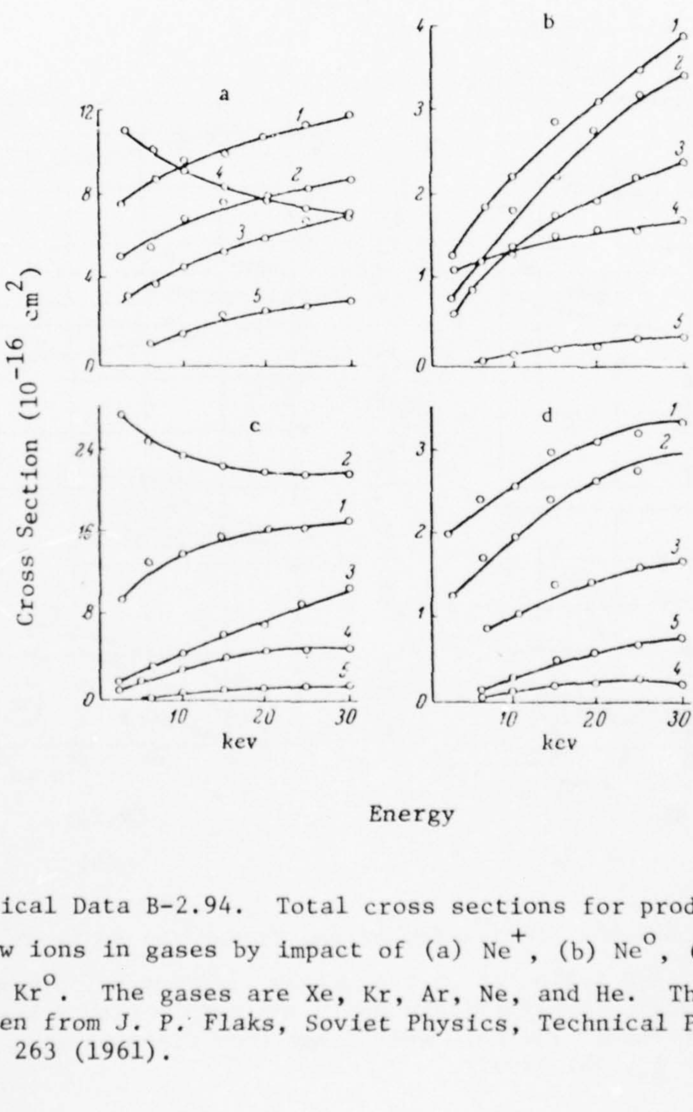


Graphical Data B-2.93a. Total cross sections for production of free electrons in gases by impact of (a) Ne^+, (b) Ne^o, (c) Kr^+, and (d) Kr^o. The gases are Xe, Kr, Ar, Ne, and He. The data were taken from I. P. Flaks, Soviet Physics, Technical Physics 31, 263 (1961).



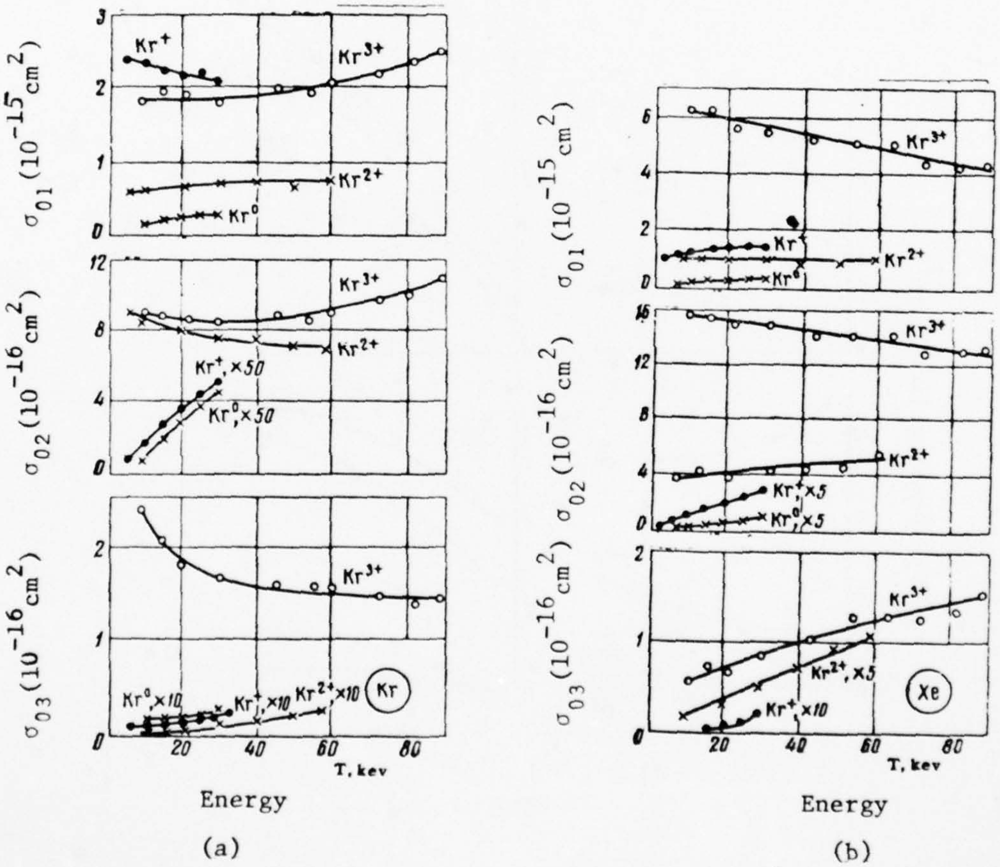
Graphical Data B-2.93b. Total cross sections for production of electrons by various multiply charged ions (individually identified on the graphs) on Ne, Kr, and Xe (identified in circle). The data were taken from Fedorenko et al., Soviet Physics, JETP 11, 519 (1960) and Flaks et al., Soviet Physics JETP 14, 1027 (1962).

Introduction The slow ions produced by impact of a heavy atom on a target represent ionization of the target only plus a component due to electron pick up by the projectile. Data on total slow ion formation are given here. Regrettably the data are fragmentary and by no means have the scope required for modelling of nuclear pumped lasers; however they do seem to be the only significant data set in the published literature.



Graphical Data B-2.94. Total cross sections for production of slow ions in gases by impact of (a) Ne^+, (b) Ne^o, (c) Kr^+, (d) Kr^o. The gases are Xe, Kr, Ar, Ne, and He. The data were taken from J. P. Flaks, Soviet Physics, Technical Physics 31, 263 (1961).

Introduction This material refers to formation of an ion B^{m+} when a projectile A^{n+} (n times ionized) is incident on a neutral target B. The data include direct removal of target electrons by ionization as well as pick up of electrons by the projectile from the target atom in the charge transfer process. The data are fragmentary and in no sense provide the scope necessary for laser modelling; they do however appear to be the only data of this type in the literature.



Graphical Data B-2.95. Ionization of (a) Kr and (b) Xe by Kr^{o}, Kr^{+}, Kr^{2+} and Kr^{3+} (as indicated on the graphs) leading to formation of singly (top box), doubly (middle box), and triply (lower box) charged ions of the target. The data were taken from Flaks et al., Soviet Physics, JETP 14, 781 (1962).

Electron Loss and Capture for Singly Charged Heavy Ions at Energies Below 25keV/amu Traversing Various Gases

Introduction and Explanation of Symbols in Graphical Data B-2.96 (a) Through B-2.105

Electron capture and loss by singly charged ions have been quite well investigated for rare gas and halogen projectiles at energies up to about 25keV/amu. Cross sections for loss of one or more electrons by Ar^+ and Kr^+ rise rapidly from the lowest studied energies (about 50keV) to peak at about 2MeV. Cross section decreases with increasing number of electrons removed. Cross sections for one electron capture are slowly decreasing over the corresponding energy range. Little significant information is found for singly charged ions above 2MeV energy.

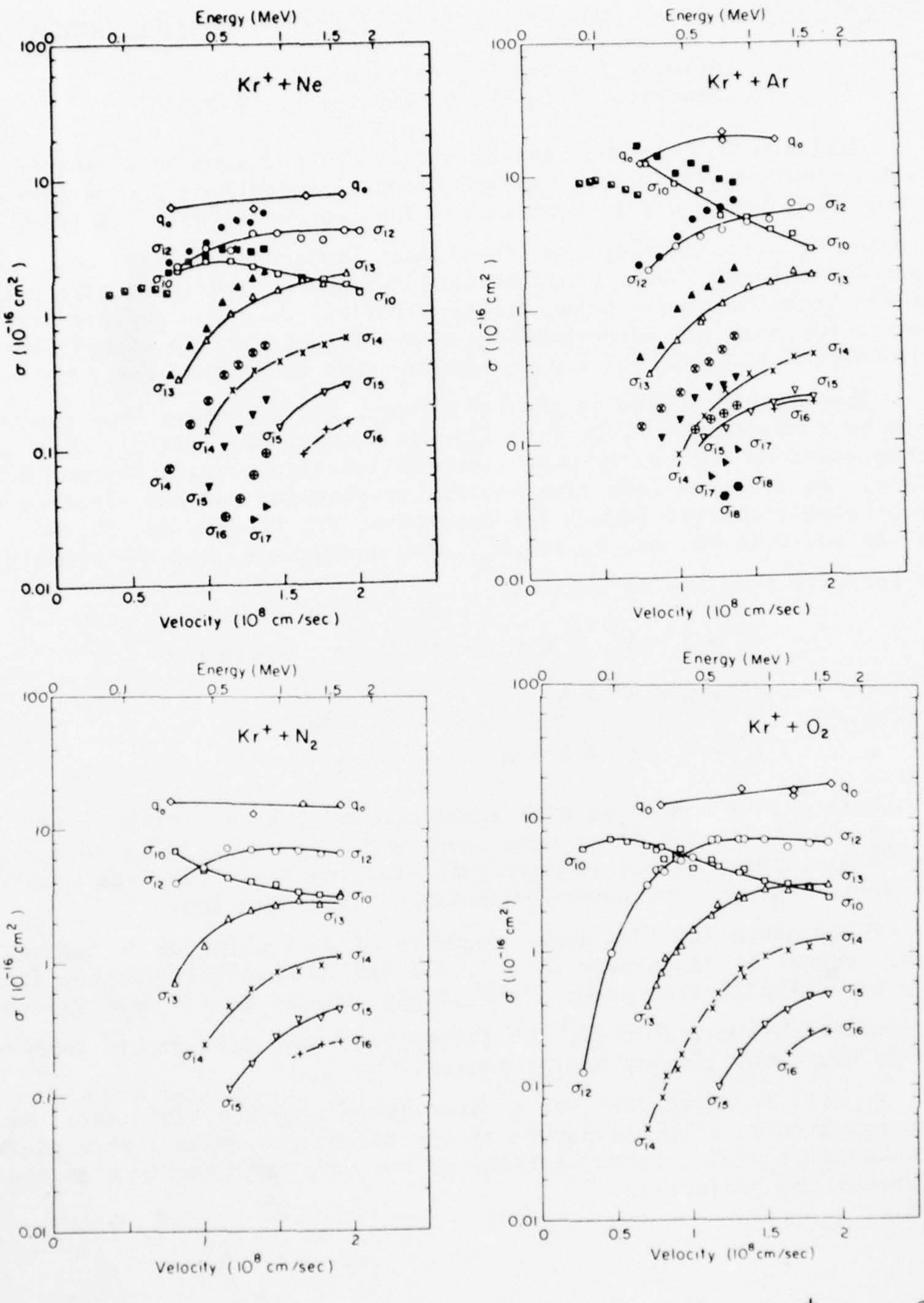
The graphical data on the following pages are drawn from the compendium by H. H. Lo and W. L. Fite (Atomic Data 1, 305 (1970)). They represent cross sections for one or more electron loss from singly charged projectiles, one electron loss from neutral projectiles and one electron pick up by singly charged ions. The data cover Kr, Sr, Rb, Ag, Sb, Xe, I, Cs, Ba and U in Ne, Ar, N_2 and O_2. The mechanisms, and the symbols used to identify them are as follows:

$A^+ + B \rightarrow A^{n+} + B + (n-1)e$	σ_{1n} where $n>1$
$A^+ + B \rightarrow A^o + B^+$	σ_{10}
$A^o + B \rightarrow A^+ + B + e$	q_o

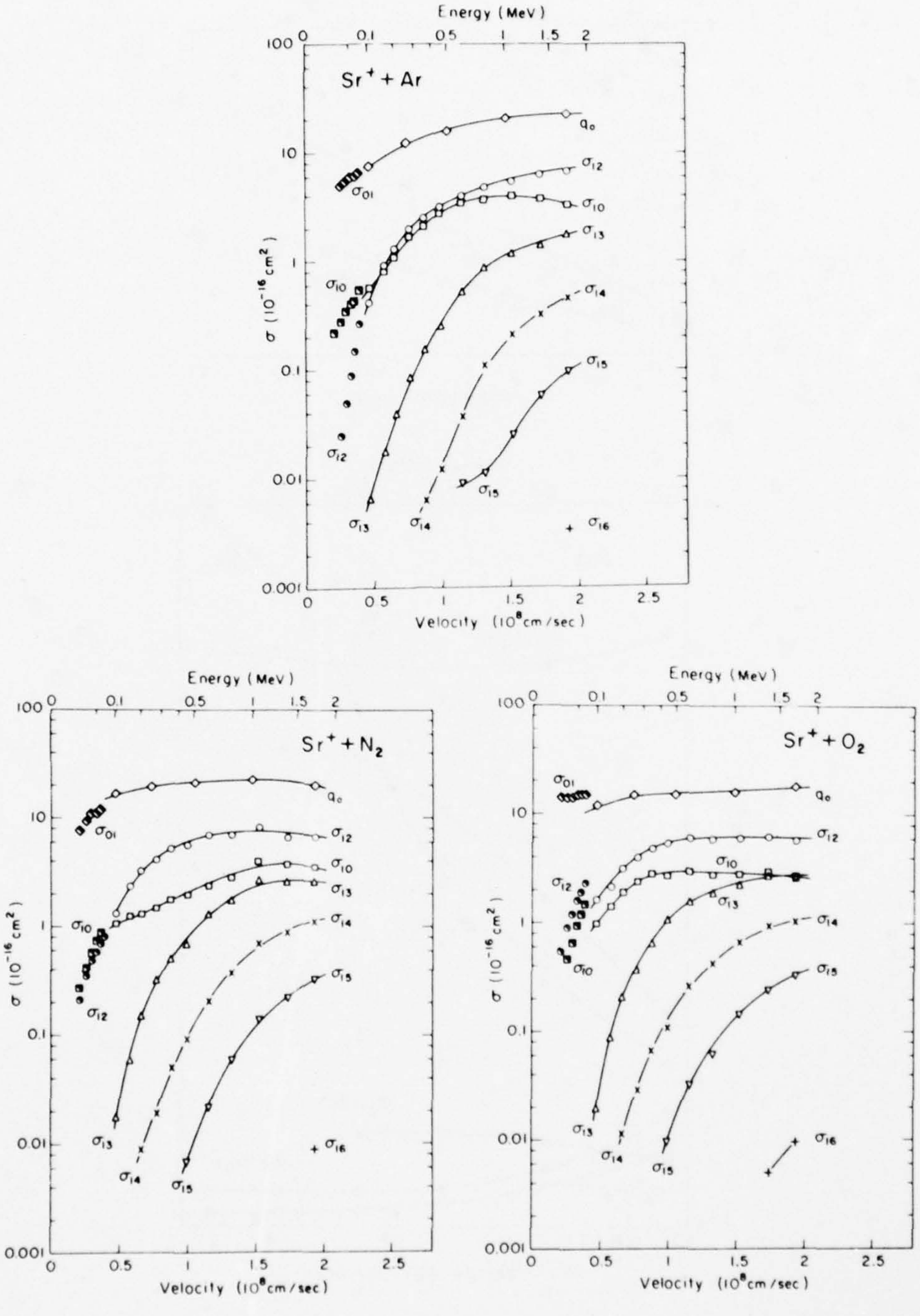
Data points connected with lines and lying at energies above 0.1 MeV are due to Lo and Fite; remaining data are due to other authors. In some cases, particularly for multiple electron loss, the data from different sources show severe unexplained discrepancies.

There are a few additional segments of data which we do not reproduce here. Dehmel et al. (Atomic Data 5, 231 (1973)) have some further fragmentary data on stripping from neutral and singly charged ions. Also Pivovar et al. (Soviet Physics, JETP 22, 508 (1966)) have some data on Kr^+ ions in Kr and Xe over very limited energy ranges.

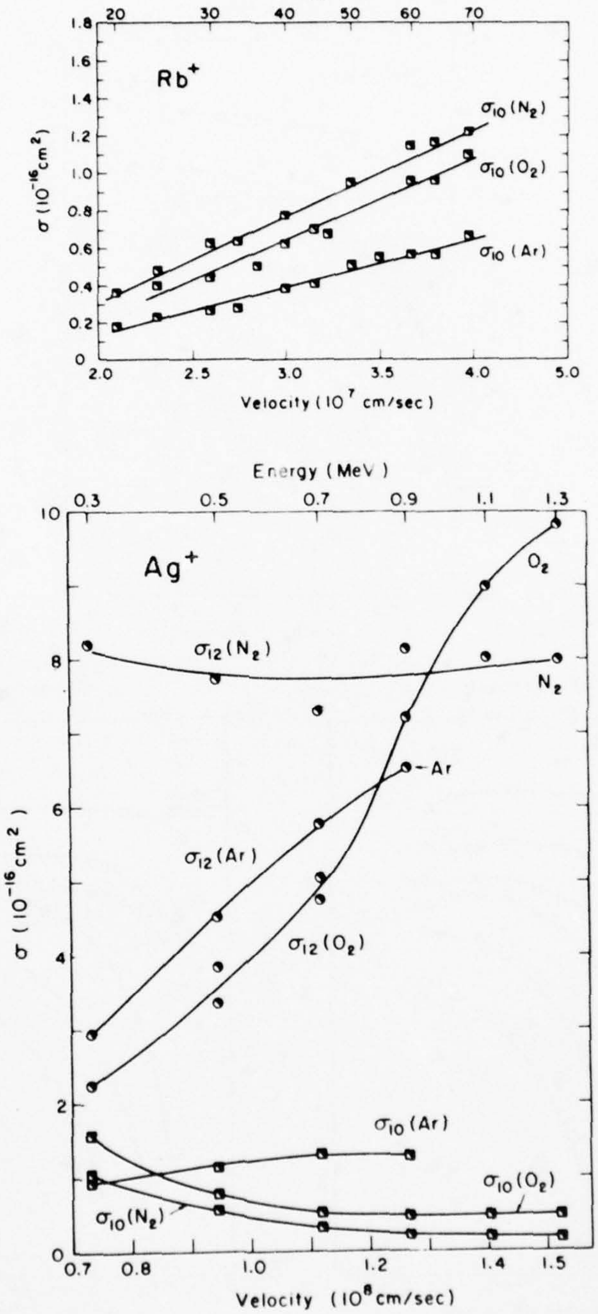
It will be noted that for a given projectile the cross sections do not vary greatly with the nature of the target gas. Also, when plotted on a velocity scale, cross sections do not vary appreciably with the nature of the projectile.



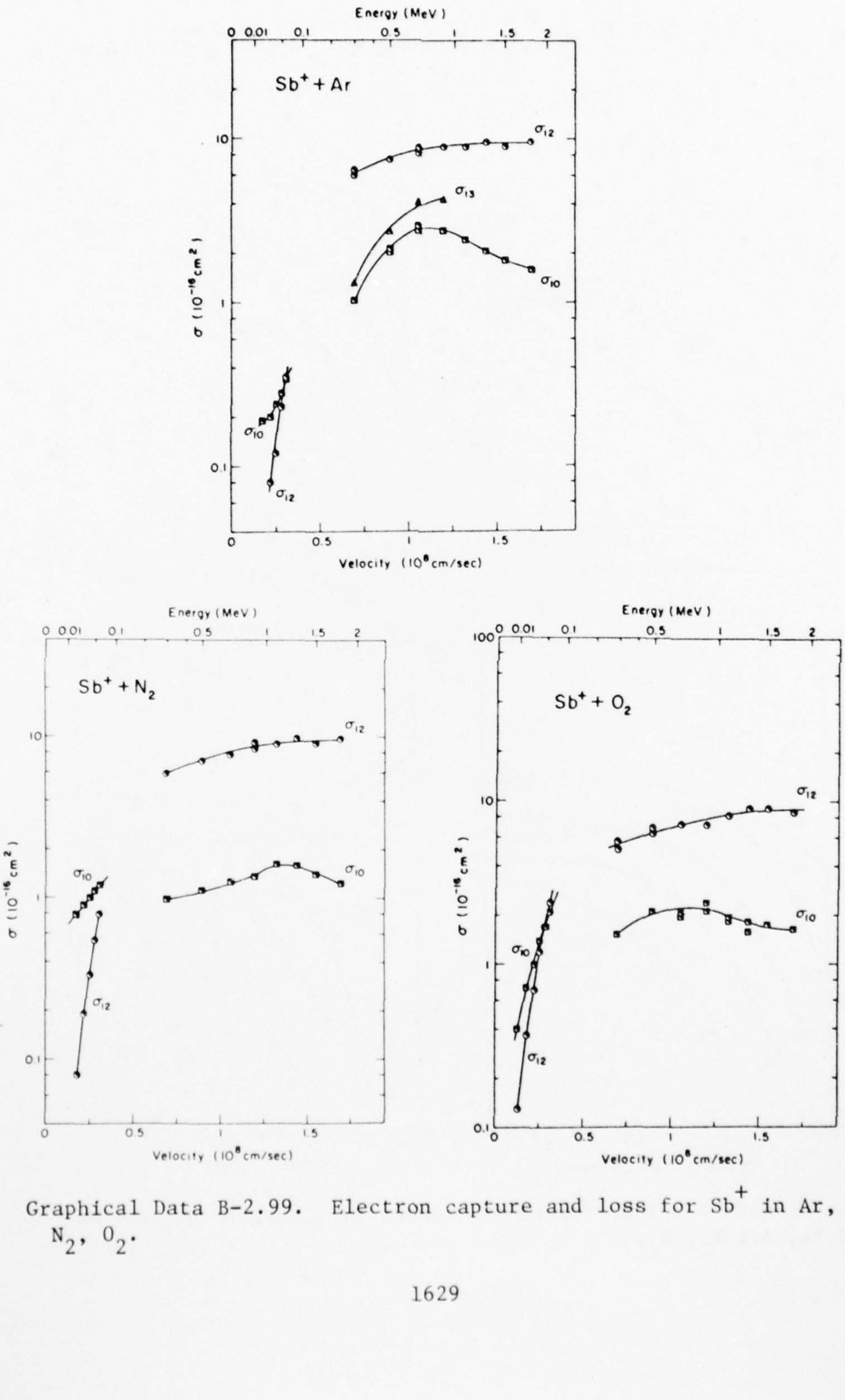
Graphical Data B-2.96. Electron capture and loss for Kr^+ and Kr^0 in Ne, Ar, N_2 and O_2.



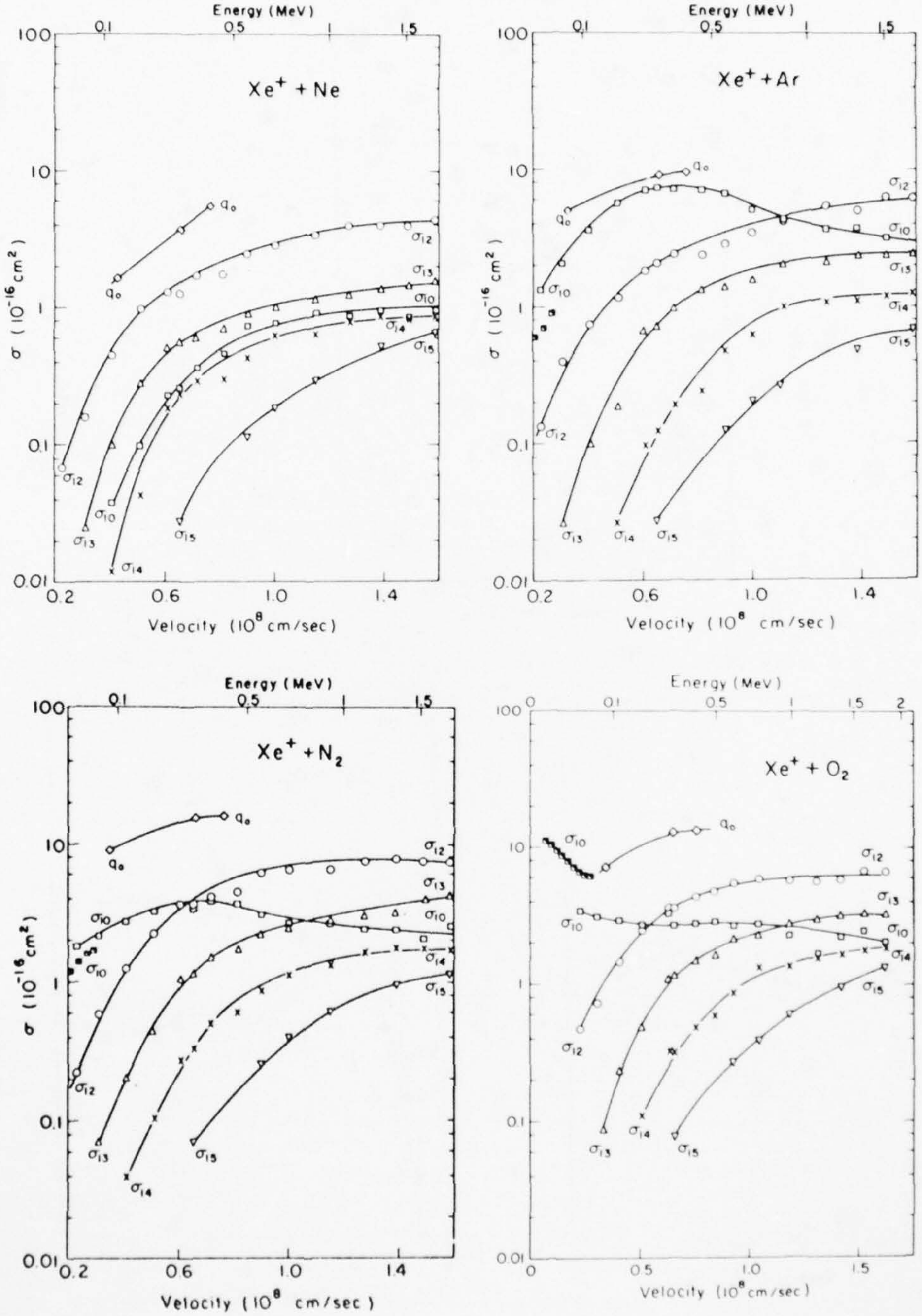
Graphical Data B-2.97. Electron capture and loss for Sr^+ and Sr^0 in Ar, N_2, O_2.



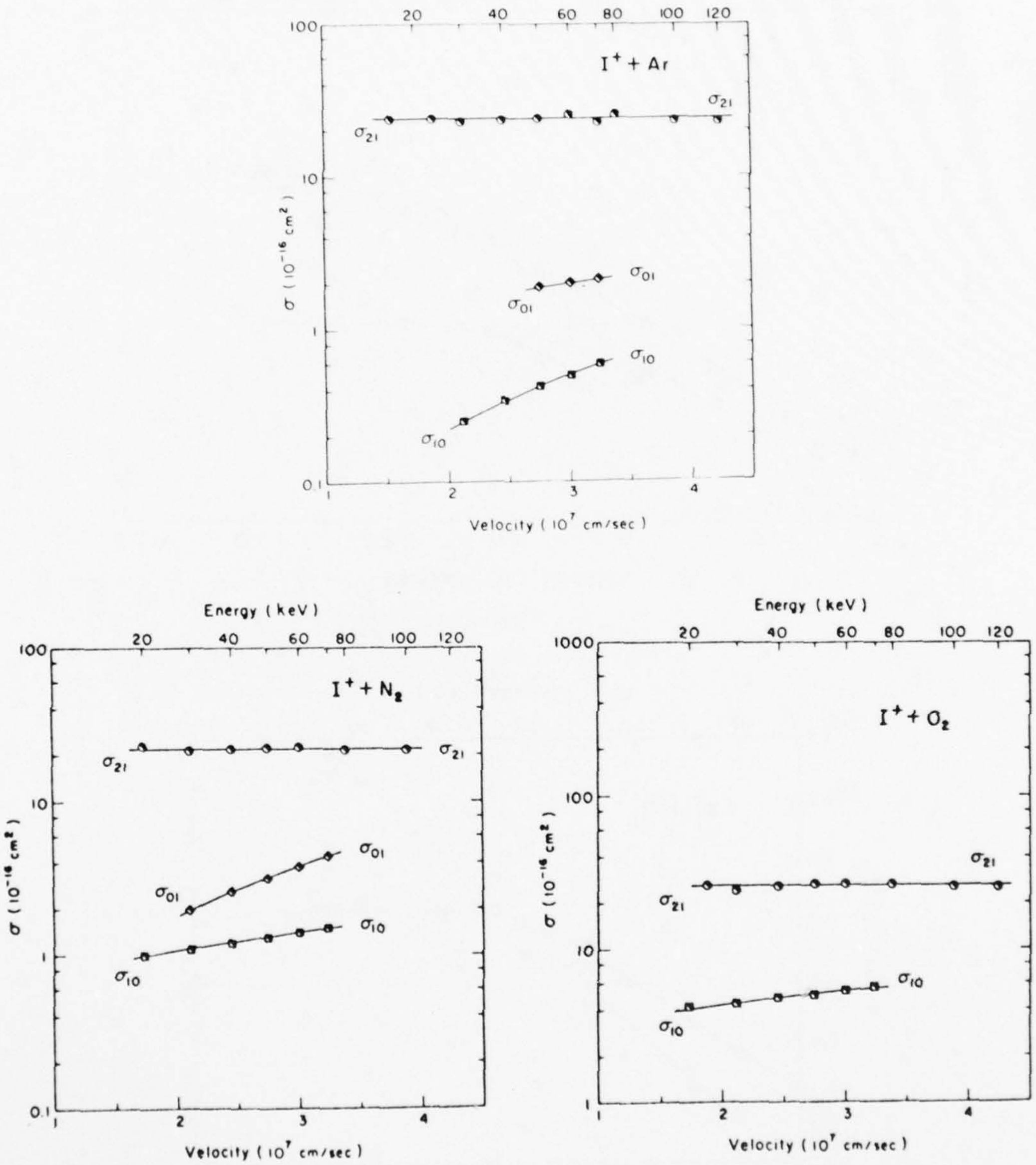
Graphical Data B-2.98. Electron capture and loss for Rb^+ and Ag^+ in Ar, N_2, O_2.



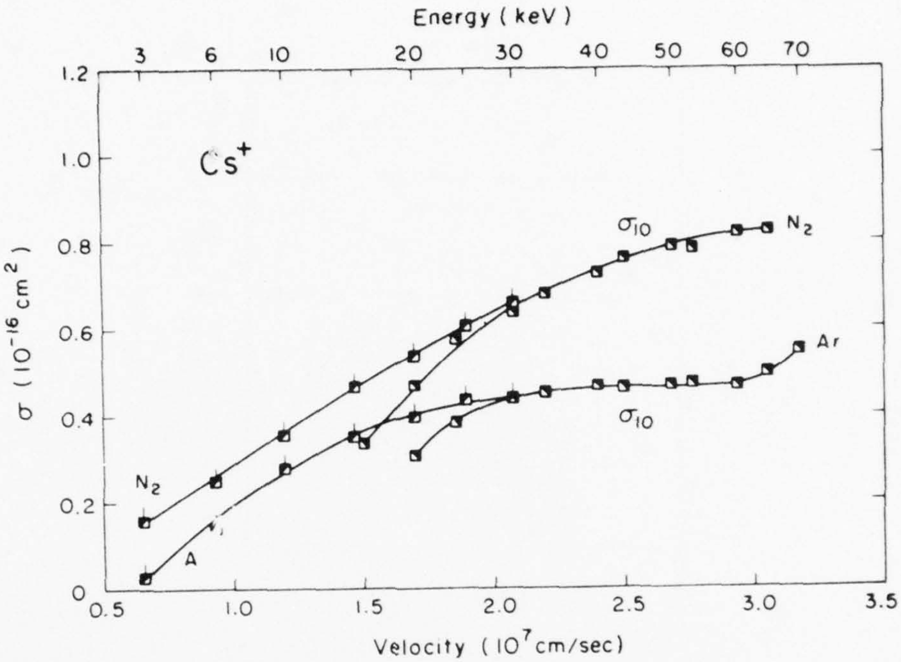
Graphical Data B-2.99. Electron capture and loss for Sb^+ in Ar, N_2, O_2.

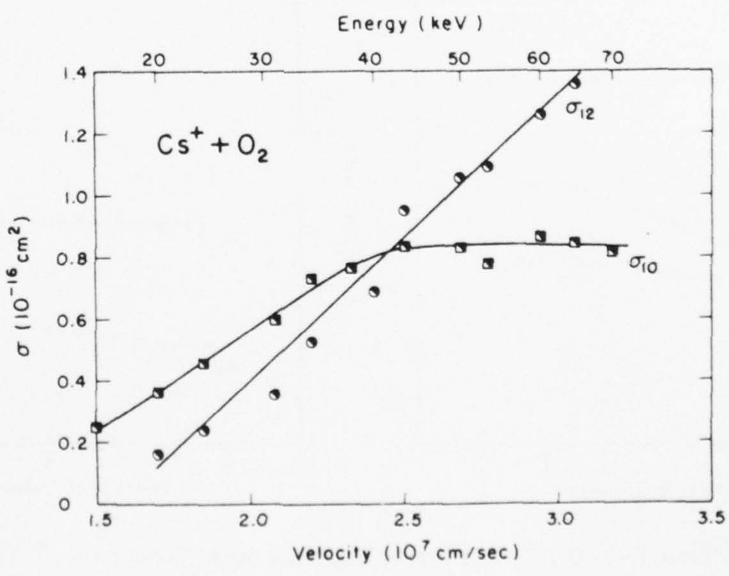


Graphical Data B-2.100. Electron capture and loss for Xe^+ and Xe in Ne, Ar, N_2, O_2.

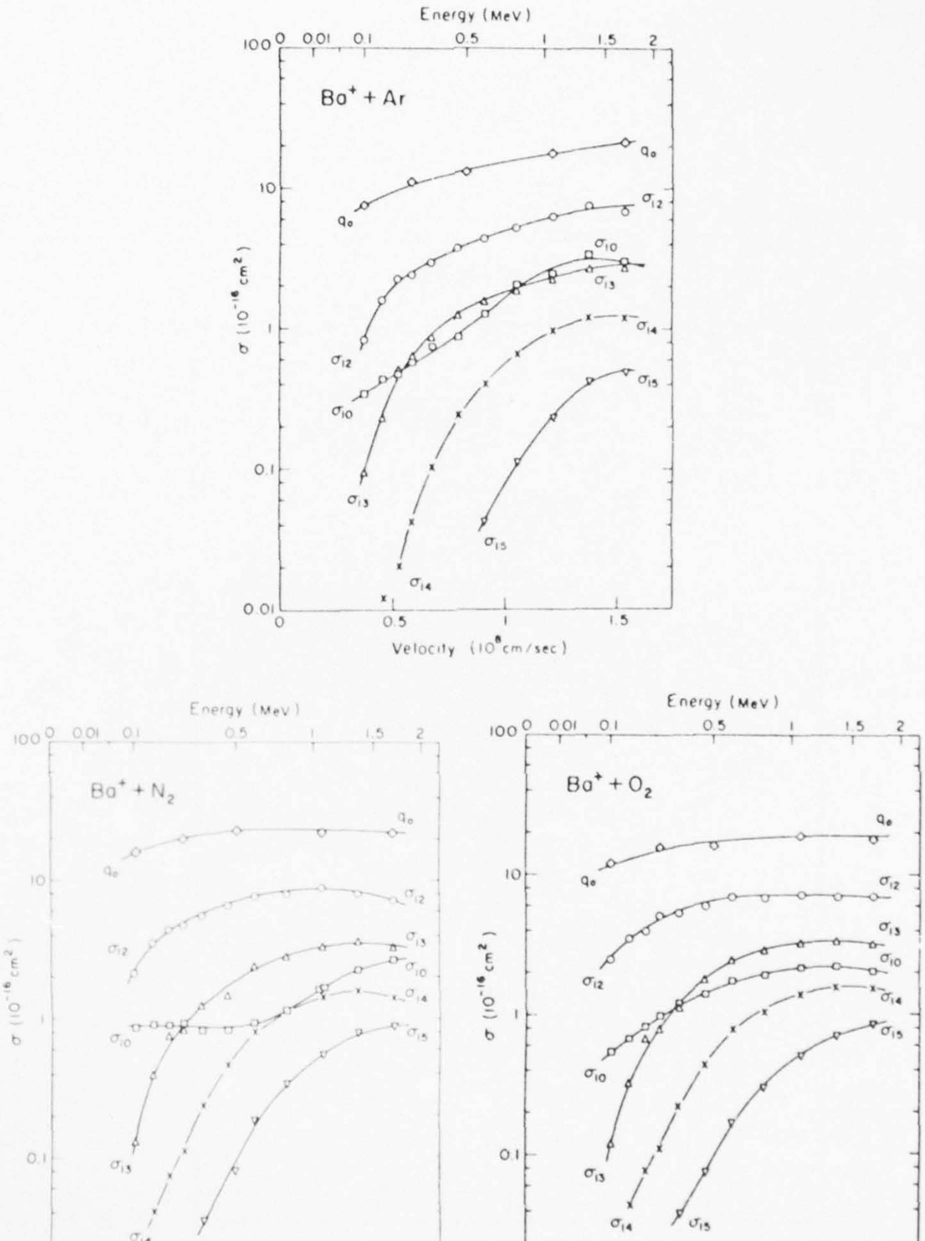


Graphical Data B-2.101. Electron capture and loss for I^+ in Ar, N_2, O_2.





Graphical Data B-2.102. Electron capture and loss for Cs^+ in Ar, N_2, O_2.

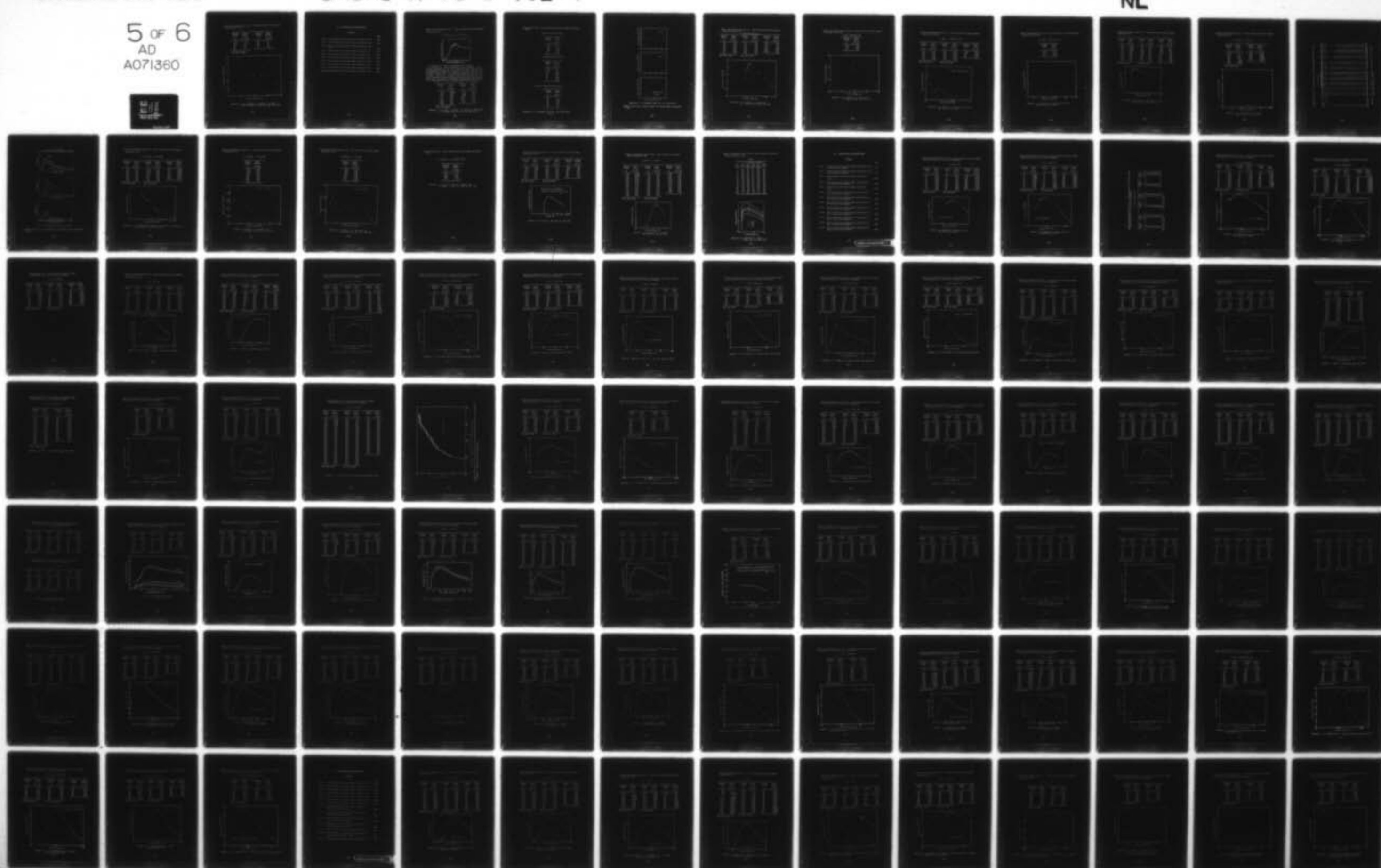


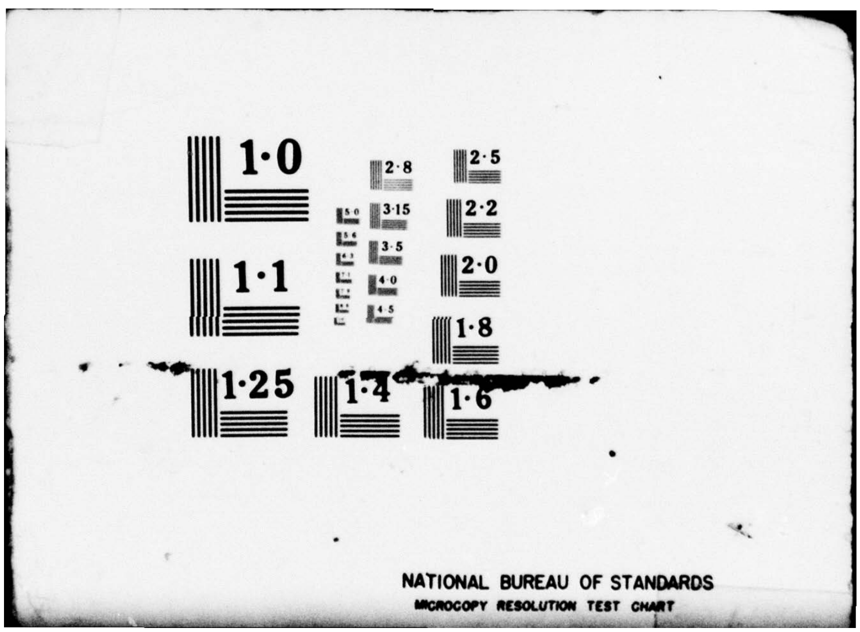
Graphical Data B-2.103. Electron capture and loss for Ba^+ in Ar, N_2, O_2.

AD-A071 360 ARMY MISSILE RESEARCH AND DEVELOPMENT COMMAND REDSTO--ETC F/G 20/5
COMPILATION OF DATA RELEVANT TO NUCLEAR PUMPED LASERS. VOLUME I--ETC(U)
DEC 78 E W MCDANIEL, M R FLANNERY, E W THOMAS

UNCLASSIFIED DRDMI-H-78-1-VOL-4 NL

5 OF 6
AD
A071360

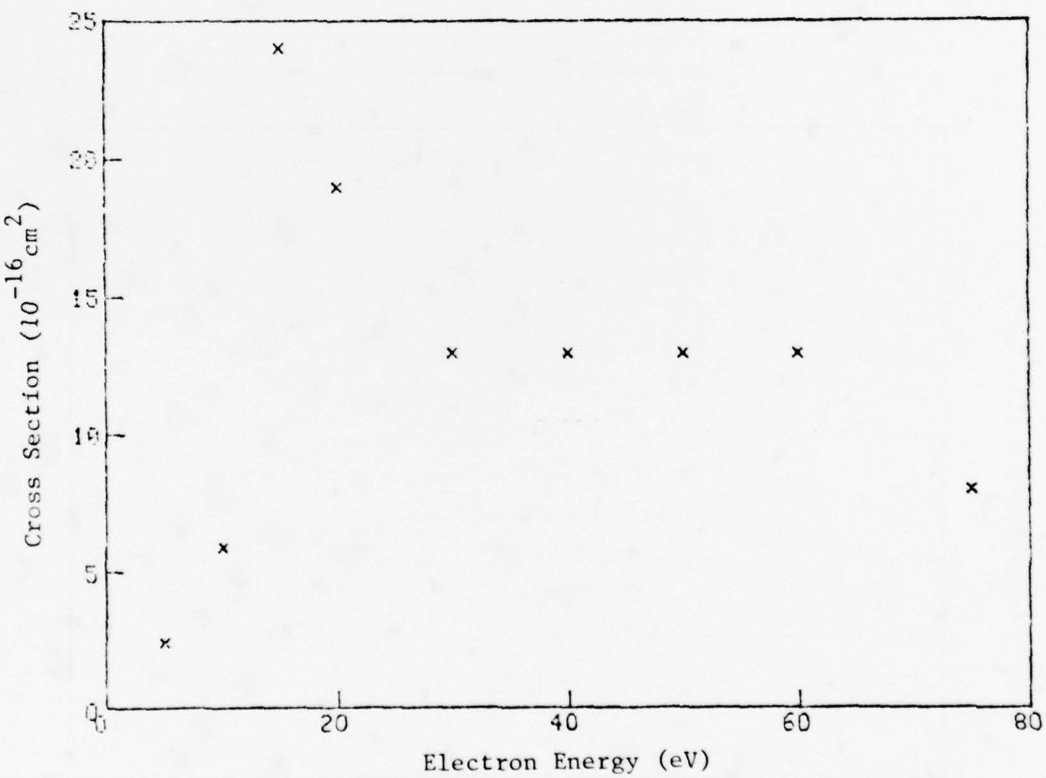



1·0
1·1
1·25
1·4
1·6
1·8
2·0
2·2
2·5
2·8
3·15
3·5
4·0
4·5
NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

Tabular and Graphical Data C-1.47. Momentum transfer cross section for electrons in UF_6.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
5.0	2.4	40	13
10.0	5.9	50	13
15	24	60	13
20	19	75	8.0
30	13		

Cont. Next Column



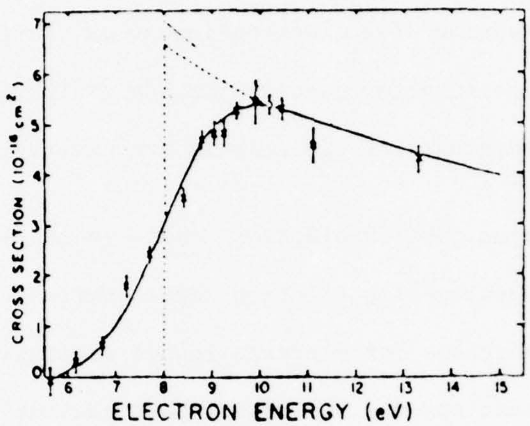
Reference: S. K. Srivastava, S. Trajmar, A. Chutjian and W. Williams, J. Chem. Phys. 64, 2767 (1976)

C-2. EXCITATION BY ELECTRON IMPACT

CONTENTS

Tabular and Graphical Data C-2.1. Cross sections for electron impact excitation of C^{3+}.

$$e + C^{3+}(2^2S_{1/2}) \rightarrow e + C^{3+}(2^2P_{1/2,3/2})$$



Cross section vs. electron energy for $e + C^{3+}(2^2S_{1/2}) \rightarrow e + C^{3+}(2^2P_{1/2,3/2})$. Open circle is an absolute measurement. Crosses are measured relative to open circle. The dashed curve: two-state close coupling from N. H. Magee, Jr., J. B. Mann, A. L. Merts, and W. D. Robb, Los Alamos Scientific Laboratory Report No. LA-6691-MS, April 1977 (unpublished). Dotted curve: Unitarized Coulomb-Born with exchange (same reference). Solid curve: "expected" cross section resulting from convolution of electron energy distribution with the two-state close-coupling calculation. Bars represent statistical uncertainties at 90% confidence level. Measured points (open circle and crosses) are tabulated below.

Electron Energy eV	Cross Section 10^{-16} cm^2	Electron Energy eV	Cross Section 10^{-16} cm^2
5.82	0.0440	9.26	4.81
6.16	0.314	9.51	5.28
6.72	0.643	9.90	5.47
7.25	1.82	10.2	5.39
7.71	2.40	10.5	5.33
8.40	3.51	11.1	4.58
8.80	4.67	13.3	4.31
9.06	4.80		

Cont. Next Column

Reference: P. O. Taylor, D. Gregory, G. H. Dunn, R. A. Phaneuf and D. H. Crandall, Phys. Rev. Lett. 39, 1256 (1977)

Tabular Data C-2.2. Cross sections for electron impact excitation of Hg.

Excitation of the 6^3P_2 State

Electron Energy eV	Cross Section $10^{-16}cm^2$
5.7	0
5.8	2.70
6.2	3.20
8.0	1.80
15	1.65
30	1.50

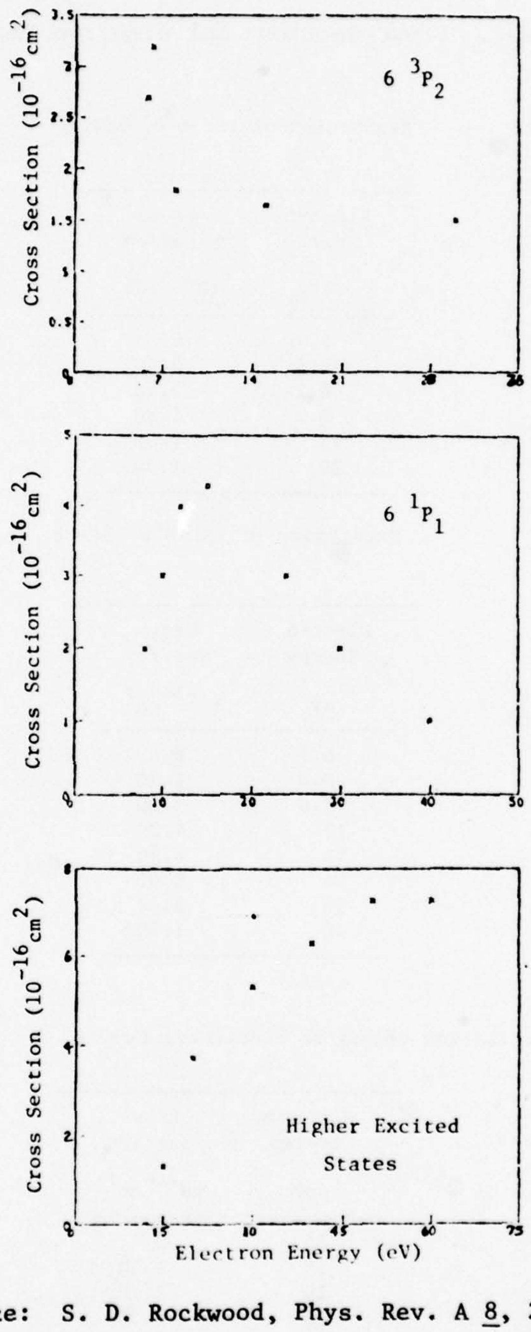
Excitation of the 6^1P_1 State

Electron Energy eV	Cross Section $10^{-16}cm^2$
6.7	0
8.0	2.00
10.0	3.00
12	4.00
15	4.30
24	3.00
30	2.00
40	1.000

Excitation of Higher Electronic Levels

Electron Energy eV	Cross Section $10^{-16}cm^2$
12	0
15	1.30
20	3.70
30	5.30
40	6.30
50	7.30
60	7.30

Reference: S. D. Rockwood, Phys. Rev. A 8, 2348 (1973)



Reference: S. D. Rockwood, Phys. Rev. A 8, 2348 (1973)

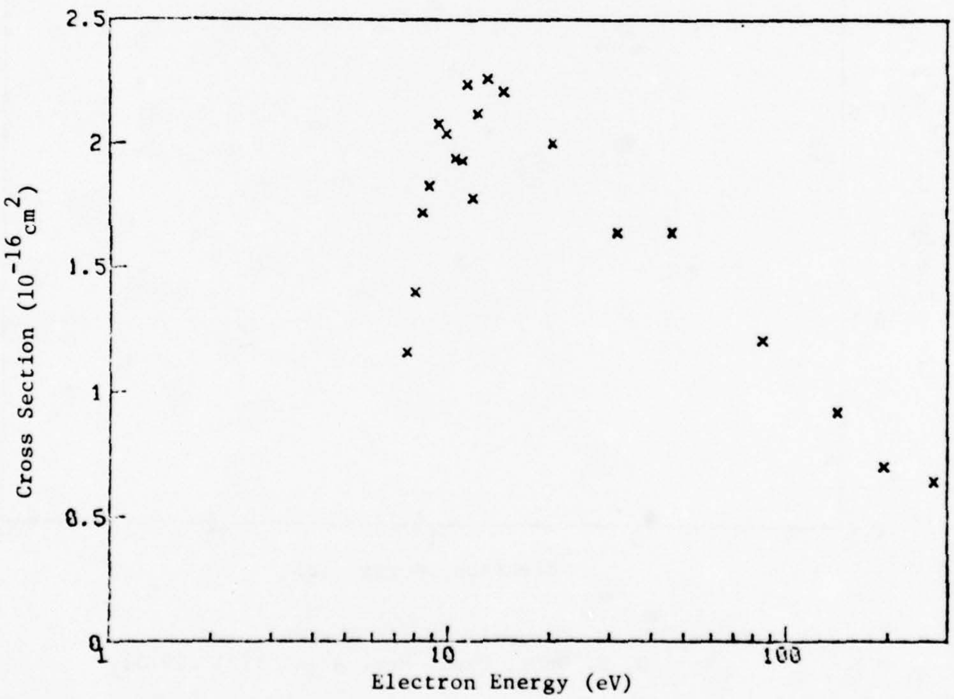
Graphical Data C-2.2. Cross sections for electron impact excitation of Hg.

Tabular and Graphical Data C-2.3a. Cross sections for electron impact excitation of Hg ions.

$e + Hg^{+} \rightarrow Hg^{+}$ (165.0 nm)

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
7.6	1.16	11.0	1.93	31.6	1.64
8.0	1.40	11.4	2.24	46.0	1.64
8.4	1.72	11.8	1.78	85.5	1.21
8.8	1.83	12.2	2.12	142.1	0.92
9.4	2.08	13.0	2.26	194.3	0.70
9.9	2.04	14.5	2.21	273.8	0.64
10.5	1.94	20.4	2.00		

Cont. Next Column   Cont. Next Column

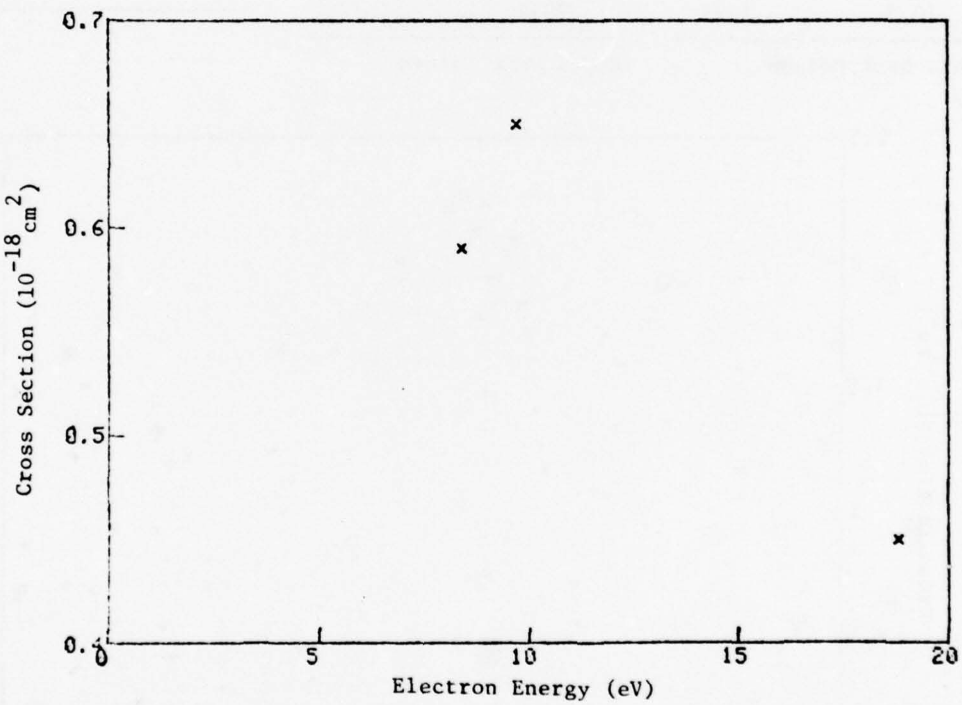


Reference: D. H. Crandall, R. A. Phaneuf and G. H. Dunn, Phys. Rev. A 11, 1223 (1975)

Tabular and Graphical Data C-2.3b. Cross sections for electron impact excitation of Hg ions.

$e + Hg^{+} \rightarrow Hg^{+}$ (398.4 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$
8.4	0.59
9.7	0.65
18.8	0.45



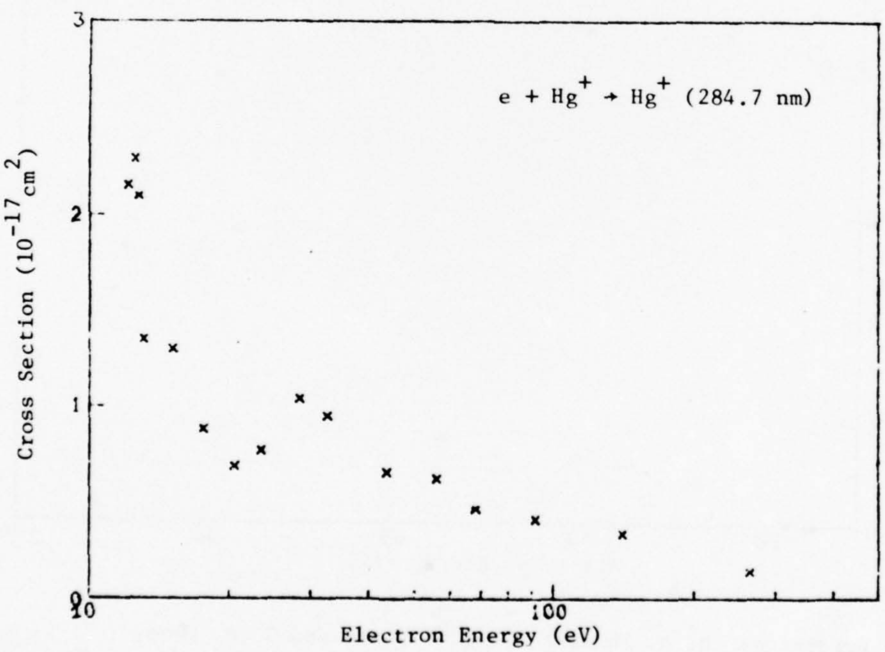
Reference: D. H. Crandall, R. A. Phaneuf, and G. H. Dunn, Phys. Rev. A 11, 1223 (1975)

Tabular and Graphical Data C-2.3c. Cross sections for electron impact excitation of Hg ions.

$$e + Hg^{+1} \rightarrow Hg^{+1} \ (284.7 \text{ nm})$$

Electron Energy eV	Cross Section $10^{-17} cm^2$	Electron Energy eV	Cross Section $10^{-17} cm^2$	Electron Energy eV	Cross Section $10^{-17} cm^2$
12.1	2.15	20.5	0.687	68.0	0.463
12.5	2.29	23.4	0.771	91.5	0.414
12.8	2.10	28.3	1.04	141	0.336
13.1	1.35	32.5	0.944	264	0.142
15.2	1.30	43.7	0.654		
17.6	0.880	56.2	0.626		

Cont. Next Column   Cont. Next Column

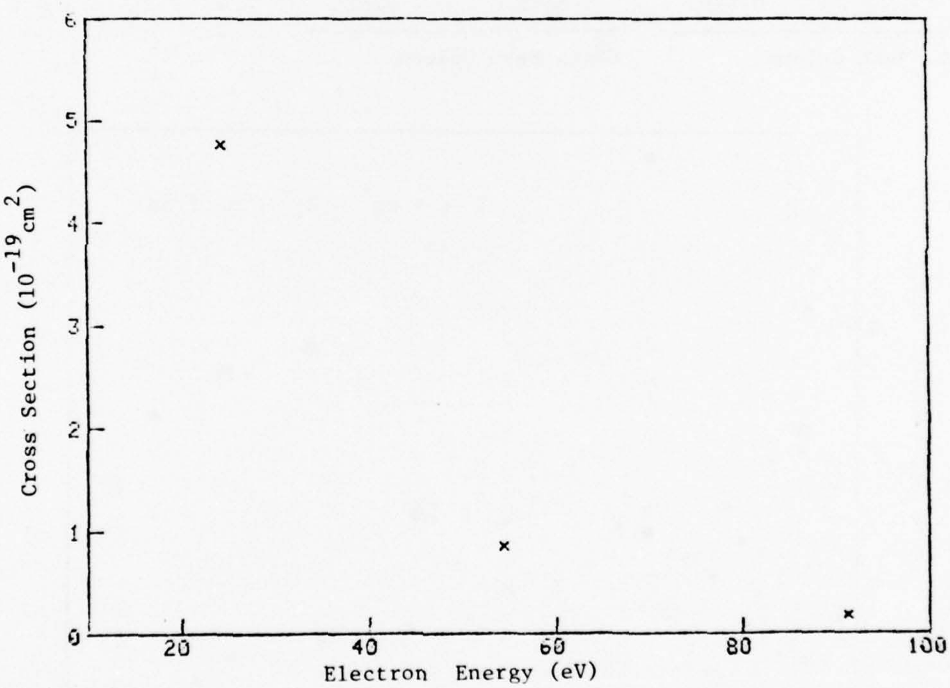


Reference: R. A. Phaneuf, P. O. Taylor, and G. H. Dunn, Phys. Rev. A 14, 2021 (1976)

Tabular and Graphical Data C-2.3d. Cross sections for electron impact excitation of Hg ions.

$$e + Hg^{2+} \rightarrow Hg^{2+} \text{ (479.7 nm)}$$

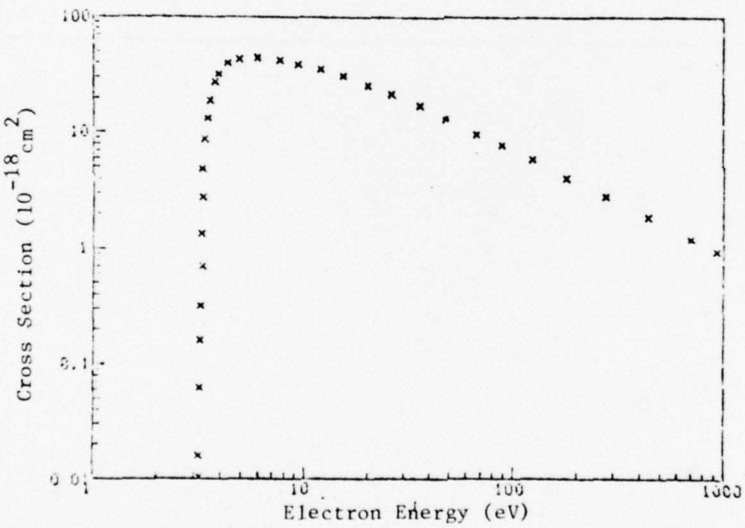
Electron Energy eV	Cross Section $10^{-19}cm^2$
24.3	4.77
54.3	0.846
91.2	0.176



Reference: R. A. Phaneuf, P. O. Taylor, and G. H. Dunn, Phys. Rev. A 14, 2021 (1976)

Tabular and Graphical Data C-2.4. Cross sections for electron impact excitation of U.

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
3.18	0.0103	3.53	19.0	26.2	21.6
3.16	0.0159	3.74	27.4	35.7	17.4
3.20	0.0627	3.89	32.0	47.6	13.2
3.20	0.160	4.28	39.9	66.8	9.61
3.21	0.317	4.87	43.3	88.9	7.83
3.25	0.697	5.93	44.7	124	5.92
3.24	1.33	7.58	42.4	179	4.09
3.25	2.74	9.28	38.8	275	2.84
3.26	4.81	11.9	35.9	439	1.86
3.35	8.65	15.2	31.1	700	1.22
3.45	13.2	20.2	26.0	928	0.956
Cont. Next Column		Cont. Next Column			



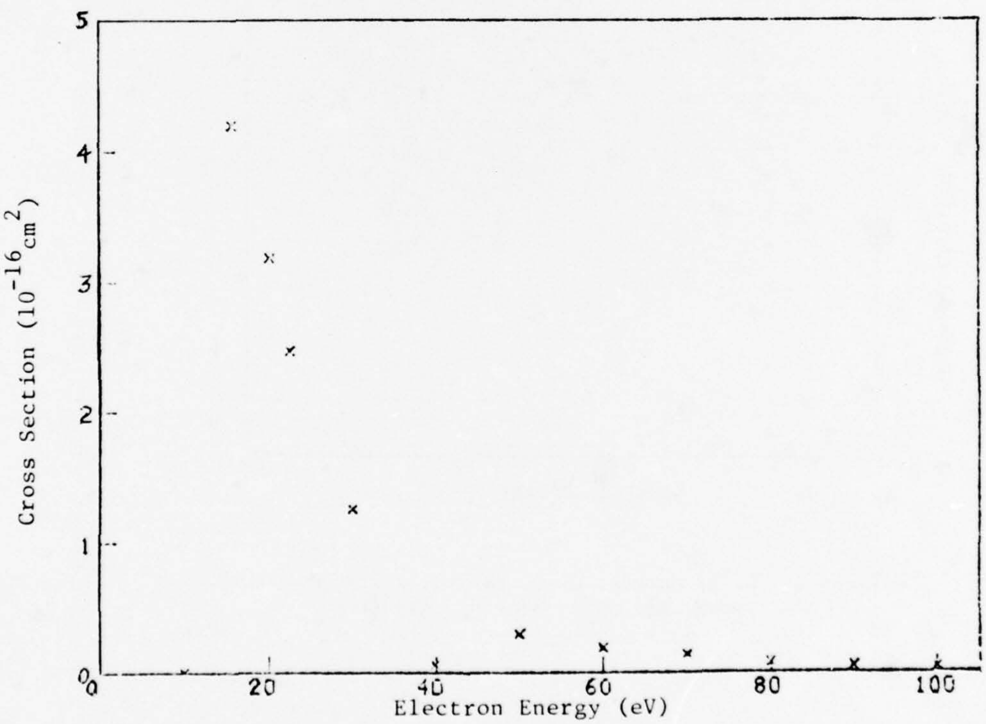
Reference: E. L. Maceda, C. G. Bathke, and G. H. Miley, Trans. Am. Nucl. Soc. 22, 153 (1975)

Tabular and Graphical Data C-2.5. Cross sections for electron impact excitation of H_2.

$$e + H_2(^3\Sigma_g^+) \rightarrow e + H_2(^3\Pi_u)$$

Electron Energy eV	Cross Section 10^{-18} cm^2	Electron Energy eV	Cross Section 10^{-18} cm^2
10.00	0	60.0	0.190
15.6	4.20	70.0	0.140
20.0	3.19	80.0	0.0760
22.5	2.48	90.0	0.0590
30.0	1.26	100	0.0460
40.0	0.0590		
50.0	0.300		

Cont. Next Column



Reference: G. R. Mohlmann and F. J. de Heer, Chem. Phys. Lett. 43, 240 (1976)

Tabular Data C-2.6. Cross sections for electronic impact excitation of N_2.

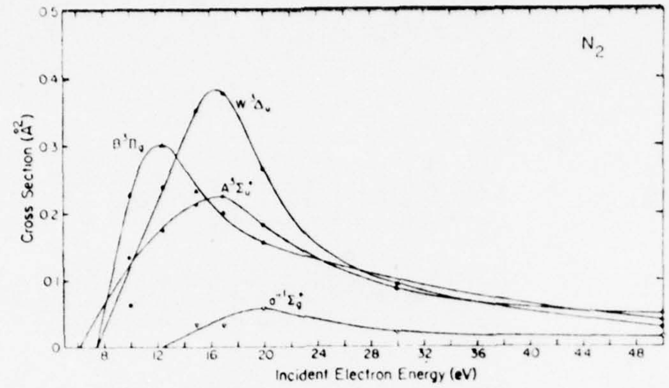
$$e + N_2 \rightarrow N_2^*$$

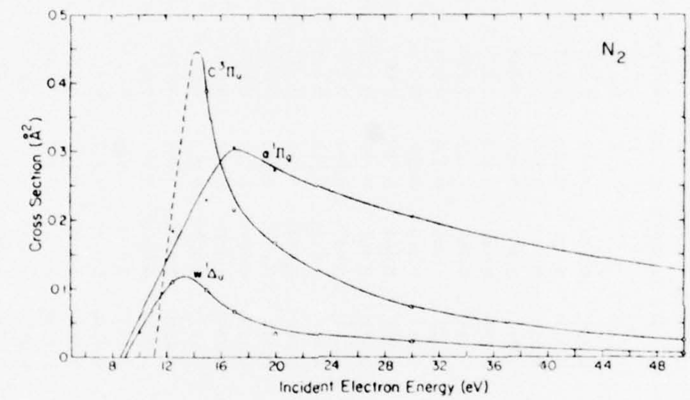
Units are 10^{-16} cm^2

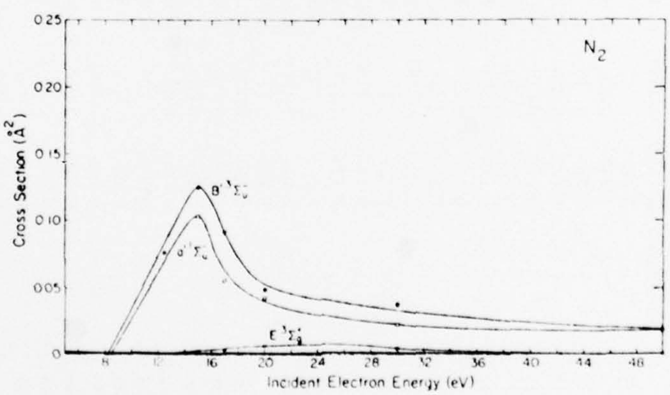
E_0 (eV)		$A^3\Sigma_u^+$	$B^3\Pi_g$	$W^3\Delta_u$	$B'^3\Sigma_u^-$	$a'^1\Sigma_u^-$	$a^1\Pi_g$	$w^1\Delta_u$	$C^3\Pi_u$	$E^3\Sigma_g^+$	$a''^1\Sigma_g^+$
	(threshold)	(6.1693)	(7.3529)	(7.3623)	(8.1647)	(8.3987)	(8.5189)	(8.8948)	(11.0316)	(11.8766)	(12.2530)
7		0.030	...	...	...	...	...	...	...	...	...
8		0.062	0.054	0.027	...	...	...	...	...	...	...
9		0.094	0.140	0.074	0.016	0.010	0.019	0.002	...	...	...
10		0.122	0.225	0.120	0.035	0.027	0.059	0.039	...	...	...
11		0.148	0.278	0.166	0.055	0.045	0.099	0.071	...	...	...
12		0.171	0.299	0.213	0.074	0.062	0.140	0.099	0.146	0.0005	...
13		0.189	0.297	0.260	0.094	0.080	0.180	0.117	0.298	0.001	0.008
14		0.204	0.271	0.306	0.113	0.096	0.220	0.115	0.443	0.0021	0.018
15		0.215	0.241	0.351	0.125	0.104	0.256	0.100	0.389	0.0030	0.028
16		0.223	0.216	0.380	0.111	0.085	0.286	0.081	0.284	0.0040	0.037
17		0.225	0.195	0.376	0.092	0.064	0.302	0.066	0.234	0.0050	0.045
18		0.214	0.179	0.350	0.073	0.052	0.297	0.056	0.202	0.0056	0.052
19		0.199	0.166	0.309	0.061	0.0455	0.287	0.049	0.181	0.0062	0.057
20		0.183	0.156	0.265	0.054	0.041	0.276	0.043	0.165	0.0070	0.058
22		0.155	0.142	0.197	0.047	0.0345	0.258	0.036	0.139	0.0078	0.051
24		0.132	0.130	0.153	0.043	0.0300	0.242	0.032	0.118	0.0080	0.011
26		0.113	0.120	0.126	0.0395	0.0275	0.228	0.029	0.100	0.0080	0.034
28		0.099	0.110	0.108	0.0363	0.0250	0.216	0.026	0.086	0.0065	0.028
30		0.087	0.101	0.094	0.0337	0.0230	0.204	0.023	0.074	0.0050	0.023
32		0.078	0.092	0.0835	0.0313	0.0215	0.194	0.021	0.066	0.0040	0.020
34		0.072	0.084	0.074	0.0292	0.0200	0.184	0.018	0.059	0.0032	0.019
36		0.066	0.076	0.066	0.0275	0.0195	0.175	0.016	0.052	0.0027	0.017
38		0.062	0.070	0.059	0.0260	0.0187	0.166	0.014	0.047	0.0020	0.0165
40		0.058	0.064	0.052	0.0245	0.0185	0.159	0.013	0.042	0.0018	0.016
42		0.056	0.058	0.017	0.0230	0.0184	0.152	0.011	0.038	0.0013	0.015
44		0.054	0.054	0.012	0.0220	0.0183	0.145	0.010	0.034	0.0010	0.015
46		0.052	0.049	0.038	0.0210	0.0182	0.139	0.009	0.031	0.0009	0.0145
48		0.501	0.045	0.034	0.0200	0.0181	0.134	0.008	0.028	0.0008	0.0144
50		0.050	0.040	0.030	0.0190	0.0180	0.127	0.007	0.026	0.0007	0.0143

Reference: D. C. Cartwright, S. Trajmar, A. Chutjian, and W. Williams, Phys. Rev. A 16, 1041 (1977)

Units are $Å^2 = 10^{-16} cm^2$







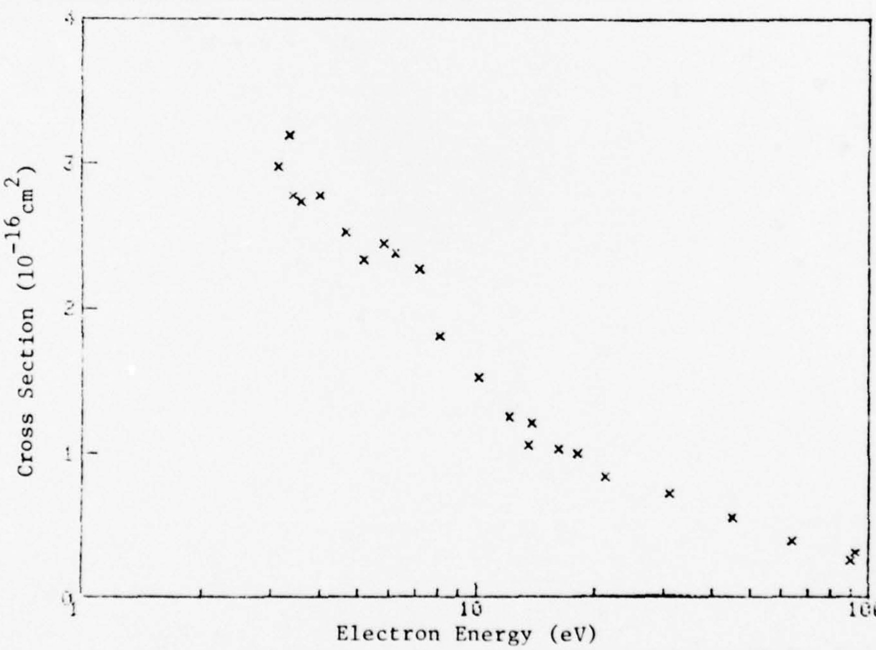
Reference: D. C. Cartwright, S. Trajmar, A Chutjian, and W. Williams, Phys. Rev. A 16, 1041 (1977)

Graphical Data C-2.6. Cross sections for electronic impact excitation of N_2.

Tabular and Graphical Data C-2.7. Cross sections for electron impact excitation of N_2^+.

$$e + N_2^+(X^2\Sigma_g^+) \rightarrow e + N_2^+(B^2\Sigma_u^+)$$

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
3.15	2.97	6.27	2.37	18.2	0.994
3.37	3.19	7.19	2.26	21.4	0.835
3.43	2.77	8.08	1.80	31.2	0.718
3.61	2.73	10.2	1.52	45.2	0.553
4.02	2.78	12.2	1.25	64.1	0.393
4.68	2.52	13.7	1.05	90.0	0.257
5.21	2.33	13.9	1.20	92.8	0.312
5.87	2.44	16.4	1.02		
Cont. Next Column		Cont. Next Column			

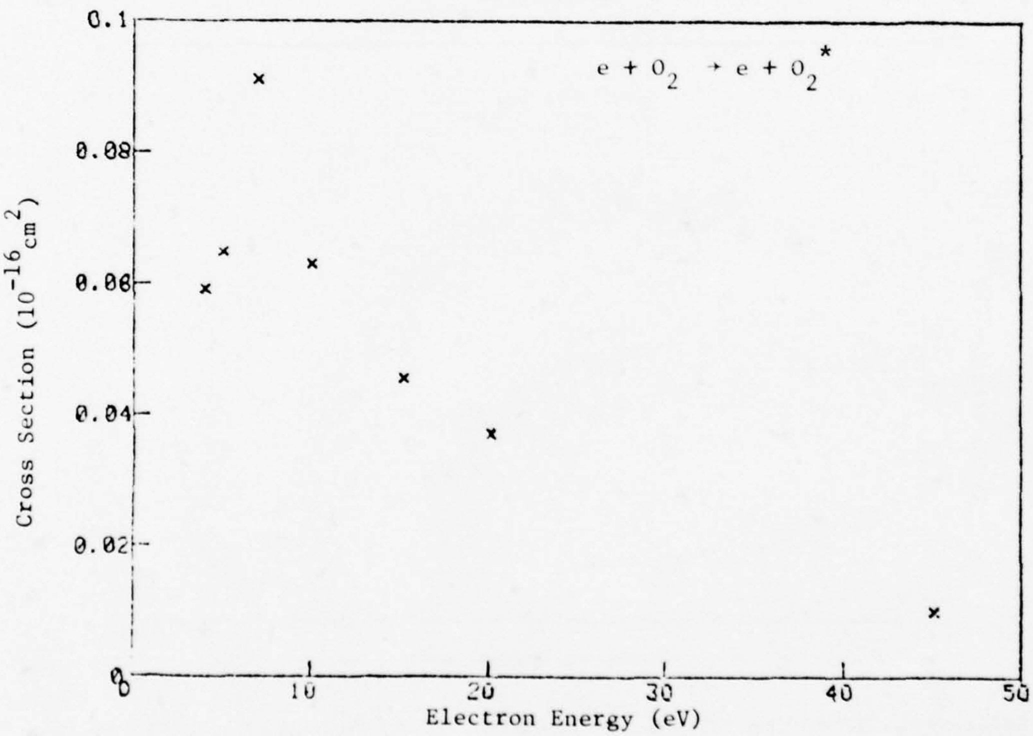


Reference: D. H. Crandall, W. E. Kauppila, R. A. Phaneuf, P. O. Taylor, and G. H. Dunn, Phys. Rev. A 9, 2545 (1974)

Tabular and Graphical Data C-2.8a. Cross sections for electron impact excitation of O_2.

$$e + O_2(X^3\Sigma_g^-) \rightarrow e + O_2(a^1\Delta_g)$$

Electron Energy eV	Cross Section $10^{-18} cm^2$
4.04	6.56
5.04	7.20
7.01	10.1
10.0	6.99
15.2	5.07
15.2	5.07
20.1	4.12
45.1	1.11

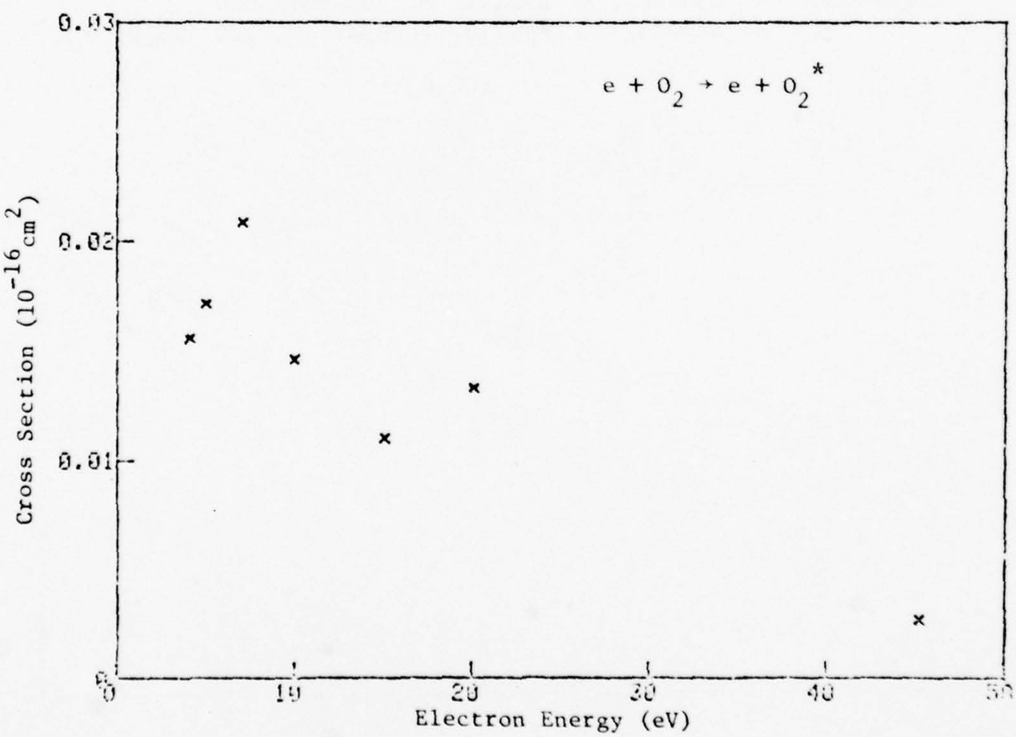


Reference: S Trajmar, D. C. Cartwright, and W. Williams, Phys. REv. A 4, 1482 (1971)

Tabular and Graphical Data C-2.8b. Cross sections for electron impact excitation of O_2.

$$e + O_2(X^3\Sigma_g^-) \rightarrow e + O_2(b^1\Sigma_g^+)$$

Electron Energy eV	Cross Section $10^{-18} cm^2$
4.09	1.56
4.97	1.72
7.07	2.09
9.95	1.46
15.1	1.10
20.1	1.34
45.2	0.270



Reference: S. Trajmar, D. C. Cartwright, and W. Williams, Phys. Rev. A 4, 1482 (1971)

Tabular Data C-2.8c. Cross sections for electron impact excitation of O_2.

$$e + O_2(X^3\Sigma_g^-) \rightarrow e + O_2(A^3\Sigma_u^+ + C^3\Delta_u)$$

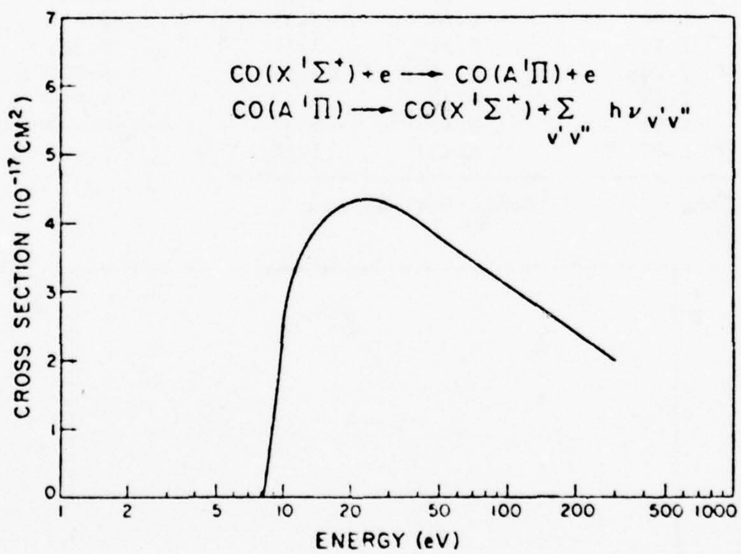
Electron Energy eV	Cross Section $10^{-18}cm^2$
19.8	2.55
30.0	13.3
50.0	4.52
70.1	5.22

Reference: A. Konishi, K. Wakiya, M. Yamamoto and H. Suzuki, J. Phys. Soc. Japan 29, 526 (1970)

Tabular and Graphical Data C-2.9. Cross sections for electron impact excitation of CO.

Electron Energy eV	Cross Section $10^{-17}cm^2$	Electron Energy eV	Cross Section $10^{-17}cm^2$	Electron Energy eV	Cross Section $10^{-17}cm^2$
8.08	0.0226	17.4	4.22	64.6	3.52
8.55	0.646	20.2	4.32	80.9	3.28
9.07	1.30	22.9	4.34	106	3.01
9.67	2.20	26.0	4.33	141	2.72
10.5	3.04	30.3	4.25	187	2.43
11.5	3.46	35.3	4.12	242	2.17
12.7	3.77	41.3	3.96	294	1.98
14.7	4.02	51.4	3.75		

Cont. Next Column   Cont. Next Column



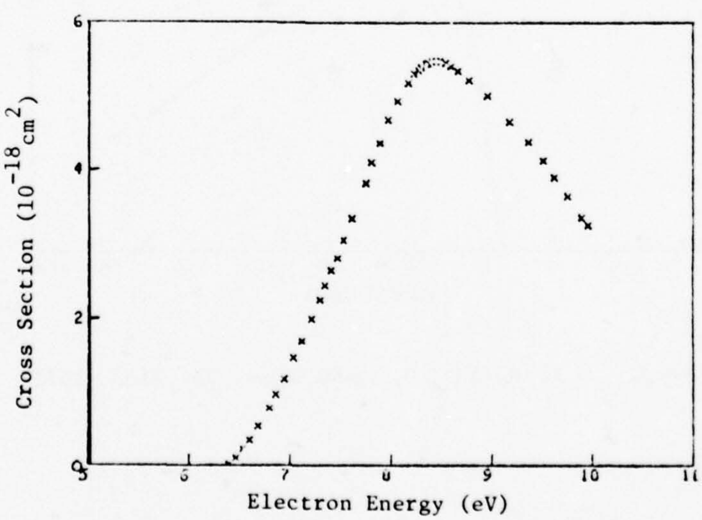
Reference: J. M. Ajello, J. Chem. Phys. 55, 3158 (1971)

Tabular and Graphical Data C-2.10a. Cross sections for electron impact excitation of NO.

$$e + NO(b^4\Sigma^-) \rightarrow e + NO(a^4\Pi)$$

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
6.39	0.0103	7.52	3.06	8.49	5.50
6.46	0.0916	7.62	3.35	8.55	5.47
6.53	0.220	7.75	3.82	8.60	5.42
6.59	0.347	7.81	4.11	8.67	5.36
6.67	0.541	7.89	4.36	8.78	5.24
6.79	0.782	7.98	4.69	8.96	5.02
6.85	0.957	8.07	4.95	9.17	4.66
6.94	1.18	8.18	5.19	9.37	4.38
7.03	1.46	8.23	5.32	9.51	4.13
7.11	1.69	8.28	5.37	9.63	3.90
7.21	1.98	8.31	5.41	9.76	3.65
7.29	2.24	8.35	5.45	9.90	3.36
7.34	2.44	8.37	5.47	9.96	3.26
7.40	2.65	8.41	5.49		
7.46	2.82	8.45	5.50		

Cont. Next Column   Cont. Next Column

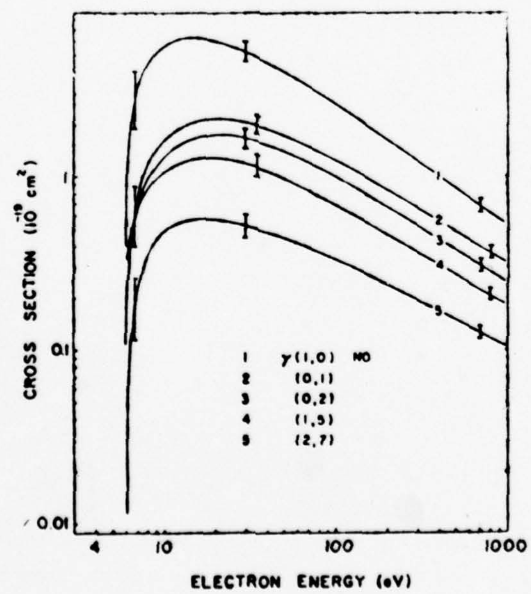


Reference: G. R. Mohlmann and F. J. de Heer, Chem. Phys. Lett. 49, 588 (1977)

Tabular and Graphical Data C-2.10b. Cross sections for electron impact excitation of NO.

γ bands

Energy (eV)	Cross section ($cm^2 \times 10^{-19}$) (0, 1) 2366 Å	(0, 2) 2474 Å	(1, 0) 2151 Å	(1, 5) 2675 Å	(2, 7) 2759 Å
6		0.34	0.4	0.10	
7	0.76	0.70	3.2	0.63	0.22
8	1.16	0.95	4.4	0.82	0.35
9	1.41	1.14	5.1	0.96	0.43
10	1.60	1.30	5.6	1.05	0.48
12	1.85	1.50	6.2	1.18	0.54
14	2.00	1.61	6.3	1.23	0.56
16	2.10	1.70	6.3	1.28	0.58
18	2.13	1.73	6.2	1.29	0.58
20	2.16	1.76	6.0	1.29	0.57
25	2.12	1.73	5.6	1.24	0.55
30	2.03	1.67	5.2	1.19	0.52
40	1.88	1.52	4.5	1.07	0.48
50	1.73	1.40	4.0	0.98	0.45
60	1.60	1.29	3.6	0.89	0.42
80	1.40	1.11	3.0	0.77	0.37
100	1.24	1.00	2.6	0.68	0.34
200	0.84	0.67	1.63	0.46	0.24
400	0.55	0.43	1.00	0.31	0.17
700	0.39	0.30	0.67	0.22	0.13
1000	0.31	0.24	0.52	0.18	0.10



Reference: M. Imami and W. L. Borst,
J. Chem. Phys. 63, 3602 (1975)

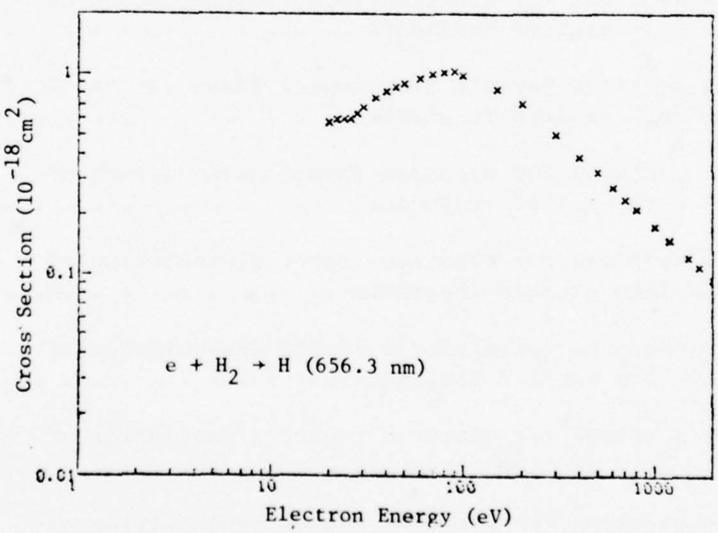
C-3. DISSOCIATION BY ELECTRON IMPACT

CONTENTS

Tabular and Graphical Data C-3.1a. Cross sections for electron impact dissociation of H_2 to form excited fragments.

$e + H_2 \rightarrow H$ (656.3 nm)

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
20	0.582	60	0.965	600	0.279
22	0.600	70	1.01	700	0.243
24	0.603	80	1.03	800	0.216
26	0.605	90	1.04	900	0.195
28	0.645	100	1.00	1000	0.177
30	0.691	150	0.853	1200	0.151
35	0.771	200	0.723	1500	0.123
40	0.832	300	0.510	1700	0.110
45	0.874	400	0.396	2000	0.0954
50	0.907	500	0.331		
Cont. Next Column		Cont. Next Column			



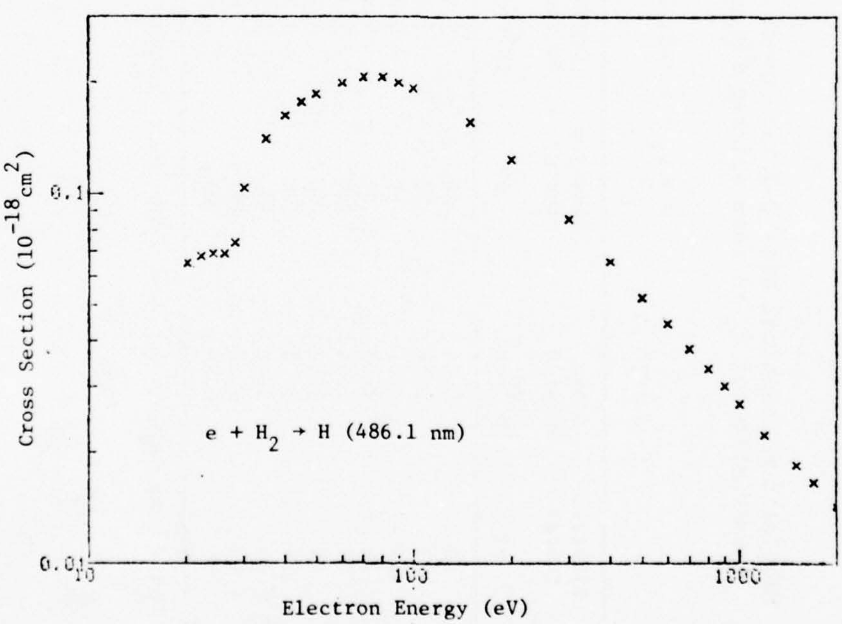
Reference: G. R. Mohlmann, F. J. de Heer and J. Los, Chem. Phys. 25, 103 (1977)

Tabular and Graphical Data C-3.1b. Cross sections for electron impact dissociation of H_2 to form excited fragments.

$e + H_2 \rightarrow H$ (486.1 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
20	0.0650	60	0.199	600	0.0446
22	0.0680	70	0.206	700	0.0381
24	0.0690	80	0.206	800	0.0336
26	0.0690	90	0.199	900	0.0302
28	0.0740	100	0.192	1000	0.0270
30	0.104	150	0.157	1200	0.0223
35	0.141	200	0.124	1500	0.0184
40	0.163	300	0.0859	1700	0.0165
45	0.177	400	0.0659	2000	0.0142
50	0.186	500	0.0526		

Cont. Next Column   Cont. Next Column



Reference: G. R. Mohlmann, F. J. de Heer, and J. Los, Chem Phys. 25, 103 (1977)

Tabular and Graphical Data C-3.1c. Cross sections for electron impact dissociation of H_2 to form exicted fragments.

$e + H_2 \rightarrow H$ (434.0 nm)

Electron Energy eV	Cross Section $10^{-20} cm^2$	Electron Energy eV	Cross Section $10^{-20} cm^2$	Electron Energy eV	Cross Section $10^{-20} cm^2$
20	1.45	60	5.59	600	1.28
22	1.54	70	5.85	700	1.10
24	1.55	80	5.82	800	0.951
26	1.55	90	5.68	900	0.849
28	1.74	100	5.38	1000	0.768
30	2.07	150	4.35	1200	0.651
35	3.03	200	3.52	1500	0.520
40	3.76	300	2.50	1700	0.460
45	4.37	400	1.88	2000	0.390
50	4.88	500	1.50		

Cont. Next Column

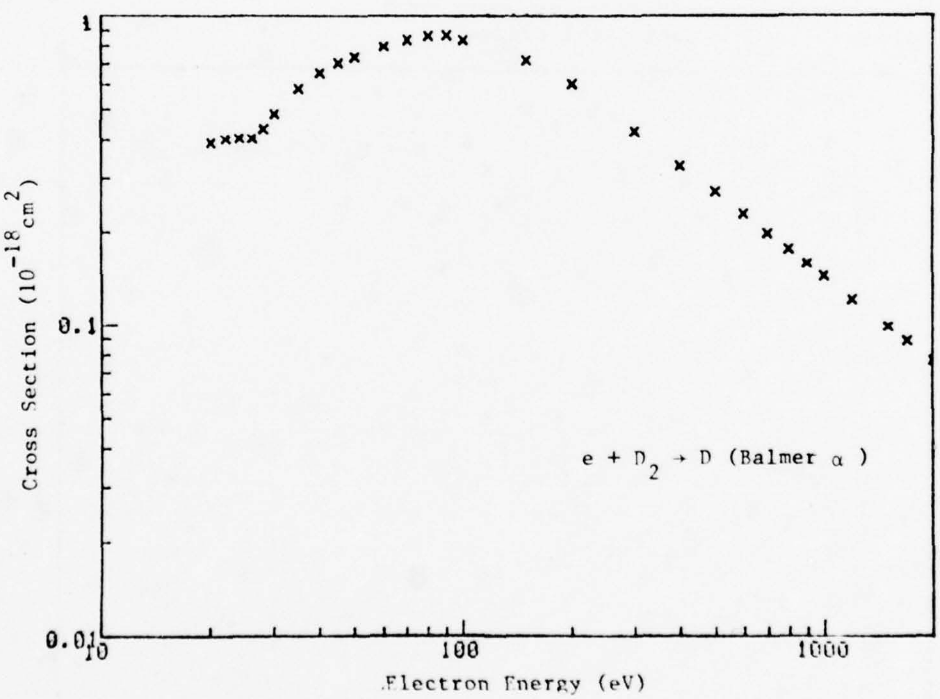
Cont. Next Column

Tabular and Graphical Data C-3.2a. Cross sections for electron impact dissociation of D_2 to form excited fragments.

$e + D_2 \rightarrow D$ (Balmer α)

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
20	0.389	60	0.799	600	0.229
22	0.400	70	0.836	700	0.198
24	0.403	80	0.861	800	0.176
26	0.403	90	0.869	900	0.158
28	0.433	100	0.840	1000	0.144
30	0.483	150	0.722	1200	0.121
35	0.587	200	0.605	1500	0.0986
40	0.657	300	0.424	1700	0.0887
45	0.707	400	0.328	2000	0.0766
50	0.740	500	0.272		

Cont. Next Column Cont. Next Column



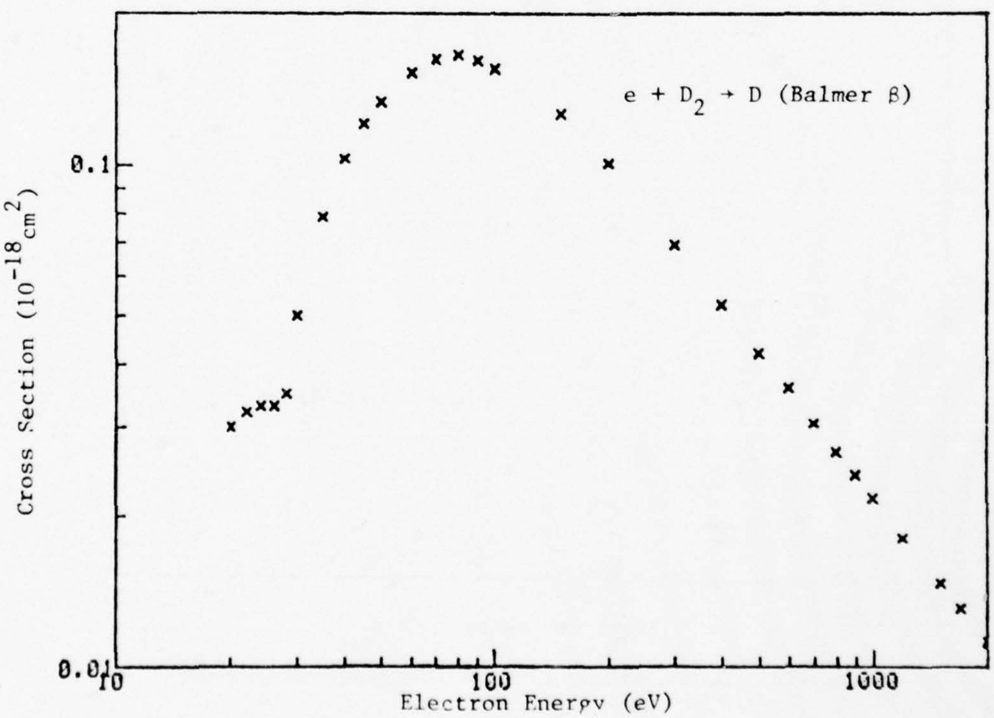
Reference: G. R. Mohlmann, F. J. de Heer, and J. Los, Chem. Phys. 25, 103 (1977)

Tabular and Graphical Data C-3.2b. Cross sections for electron impact dissociation of D_2 to form excited fragments.

$e + D_2 \rightarrow D$ (Balmer β)

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
20	0.0300	60	0.153	600	0.0360
22	0.0320	70	0.163	700	0.0305
24	0.0330	80	0.166	800	0.0267
26	0.0330	90	0.162	900	0.0240
28	0.0350	100	0.156	1000	0.0216
30	0.0500	150	0.127	1200	0.0180
35	0.0790	200	0.101	1500	0.0146
40	0.103	300	0.0693	1700	0.0130
45	0.121	400	0.0527	2000	0.0112
50	0.134	500	0.0421		

Cont. Next Column   Cont. Next Column



Reference: G. R. Mohlmann, F. J. de Heer and J. Los, Chem. Phys. 25, 103 (1977)

Tabular Data C-3.2c. Cross sections for electron impact dissociation of D_2 to form excited fragments.

$$e + D_2 \rightarrow D \text{ (Balmer } \gamma)$$

Electron Energy eV	Cross Section $10^{-20}cm^2$	Electron Energy eV	Cross Section $10^{-20}cm^2$	Electron Energy eV	Cross Section $10^{-20}cm^2$
20	0.340	60	4.37	600	1.02
22	0.364	70	4.65	700	0.887
24	0.365	80	4.74	800	0.755
26	0.369	90	4.60	900	0.669
28	0.470	100	4.34	1000	0.610
30	0.770	150	3.49	1200	0.525
35	1.71	200	2.86	1500	0.413
40	2.58	300	1.98	1700	0.362
45	3.26	400	1.53	2000	0.317
50	3.76	500	1.20		

Cont. Next Column

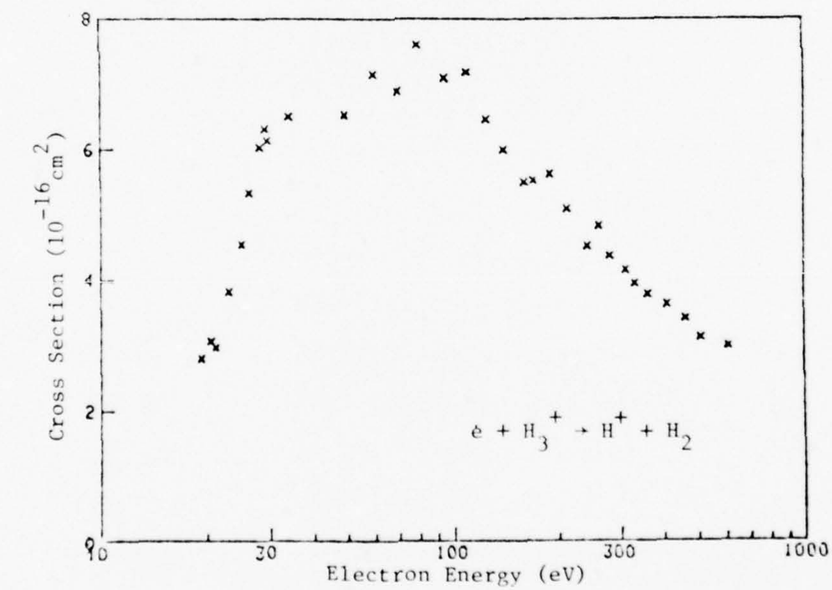
Cont. Next Column

Tabular and Graphical Data C-3.3. Cross sections for electron impact dissociation of H_3^+.

$$e + H_3^+ \rightarrow H^+ + H_2$$

Electron Energy eV	Cross Section 10^{-16}cm^2	Electron Energy eV	Cross Section 10^{-16}cm^2	Electron Energy eV	Cross Section 10^{-16}cm^2
19.2	2.80	59.0	7.16	241	4.50
20.4	3.08	69.0	6.90	261	4.83
21.0	2.98	79.0	7.60	281	4.36
22.9	3.83	94.0	7.09	311	4.15
24.8	4.54	109	7.19	331	3.94
26.1	5.34	124	6.46	361	3.78
28.1	6.04	139	5.99	411	3.62
29.5	6.14	159	5.49	461	3.41
29.0	6.32	169	5.52	511	3.12
34.0	6.52	189	5.62	611	2.99
49.0	6.54	211	5.08		

Cont. Next Column　　Cont. Next Column



Reference: B. Peart and K. T. Dolder, J. Phys. B 8, L143 (1975)

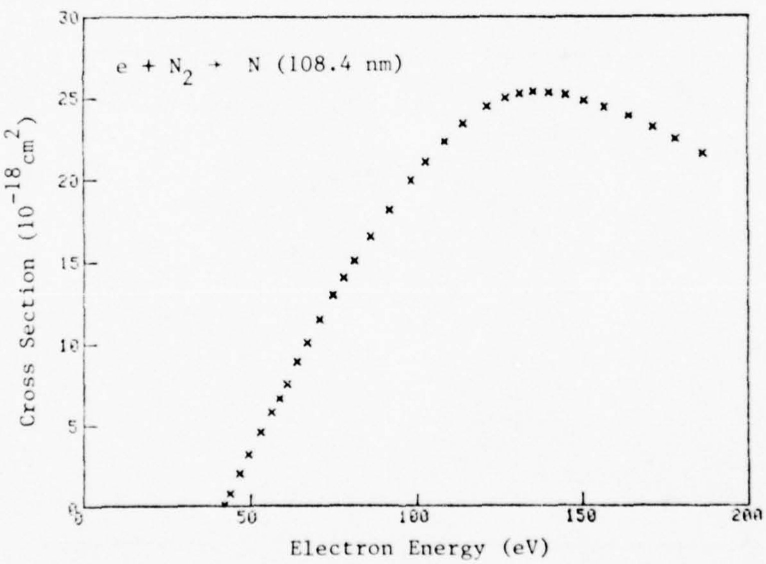
Tabular and Graphical Data C-3.4a. Cross sections for electron impact dissociation of N_2 to form excited fragments.

$e + N_2 \rightarrow N$ (108.4 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
42.1	0.109	74.7	13.0	131	25.3
43.7	0.782	78.0	14.0	135	25.4
46.6	2.03	81.3	15.1	140	25.4
49.4	3.21	86.2	16.6	145	25.2
52.8	4.56	91.9	18.2	151	24.9
56.1	5.81	98.3	20.0	157	24.5
58.4	6.66	103	21.1	164	23.9
60.7	7.55	109	22.4	172	23.2
63.8	8.93	114	23.5	178	22.5
66.8	10.1	121	24.5	187	21.6
70.6	11.5	127	25.0		

Cont. Next Column

Cont. Next Column

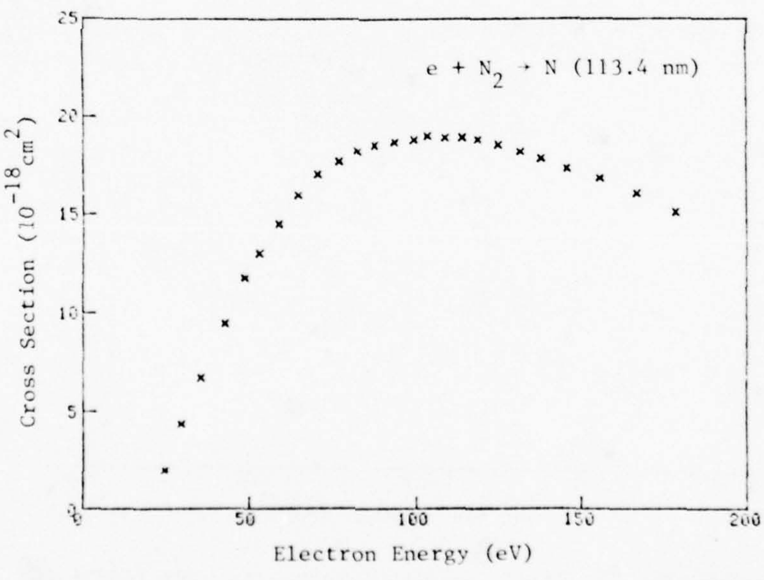


Reference: W. Sroka, Z. Naturforsch. 24a, 398 (1969)

Tabular and Graphical Data C-3.4b. Cross sections for electron impact dissociation of N_2 to form excited fragments.

$e + N_2 \rightarrow N$ (113.4 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
0.714	0.483	1.68	5.91	2.66	3.67
0.832	1.37	1.82	5.98	2.76	3.15
0.935	2.30	1.98	5.88	2.85	2.64
1.04	3.16	2.10	5.68	2.96	2.23
1.19	3.93	2.19	5.44	3.05	1.86
1.28	4.54	2.28	5.18	3.15	1.53
1.40	5.03	2.37	4.89	3.24	1.26
1.49	5.39	2.47	4.55	3.34	1.02
1.58	5.70	2.57	4.15	3.43	0.828
Cont. Next Column		Cont. Next Column		3.52	0.651
				3.63	0.482
				3.72	0.278
				3.82	0.0206



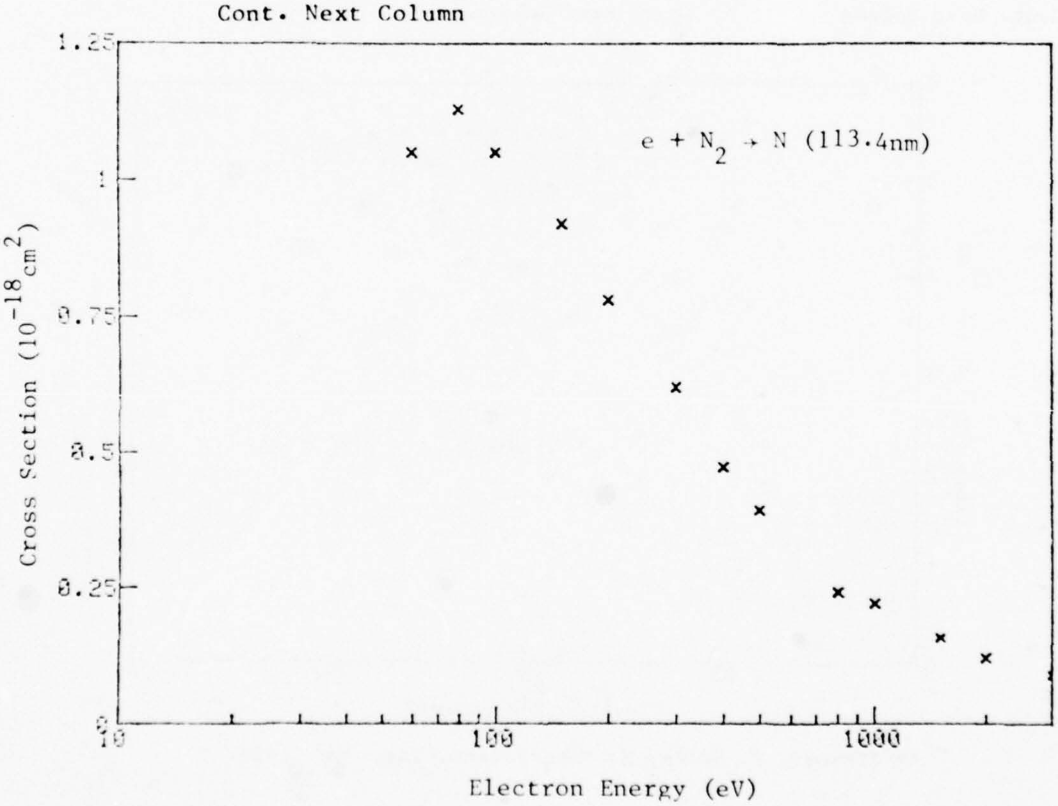
Reference: W. Sroka, Z. Naturforsch. 24a, 398 (1969)

Tabular and Graphical Data C-3.4b. Cross sections for electron impact dissociation of N_2 to give excited fragments (Concluded).

$e + N_2 \rightarrow N$ (113.4 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
60	1.05	500	0.390
80	1.13	800	0.240
100	1.05	1000	0.220
150	0.920	1500	0.157
200	0.780	2000	0.121
300	0.620	3000	0.0890
400	0.470		

Cont. Next Column



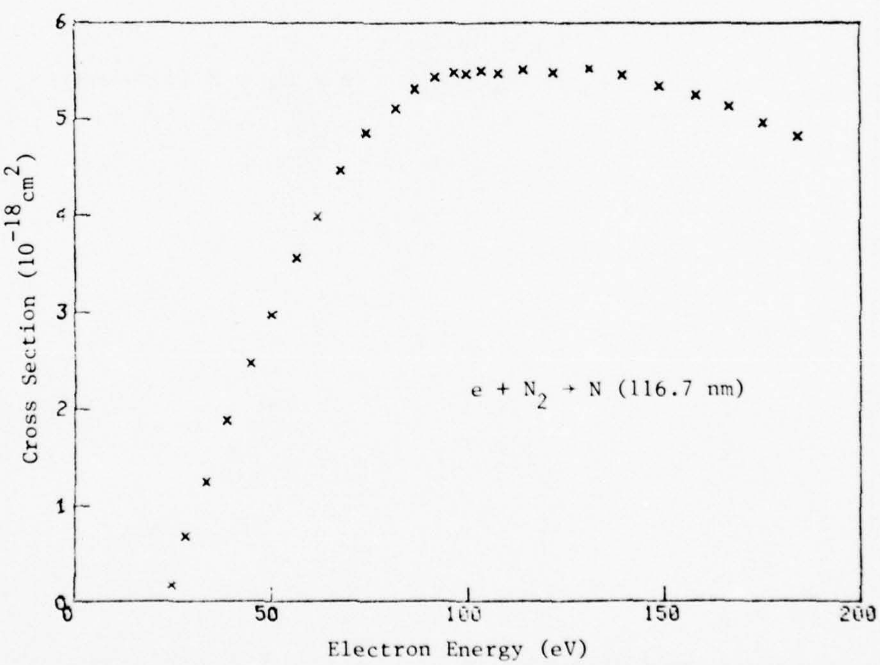
Reference: J. F. M. Aarts and F. J. de Heer, Physica 52, 45 (1971)

Tabular and Graphical Data C-3.4c. Cross sections for electron impact dissociation of N_2 to form excited fragments.

$e + N_2 \rightarrow N$ (116.7 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
24.3	0.170	74.2	4.87	122	5.49
27.9	0.680	81.5	5.12	131	5.54
33.1	1.25	86.5	5.32	140	5.46
38.7	1.88	91.8	5.44	149	5.36
44.6	2.47	96.5	5.49	158	5.26
49.9	2.97	99.7	5.48	167	5.15
56.4	3.56	104	5.51	175	4.97
61.6	4.00	108	5.48	184	4.83
67.4	4.47	114	5.52		

Cont. Next Column   Cont. Next Column



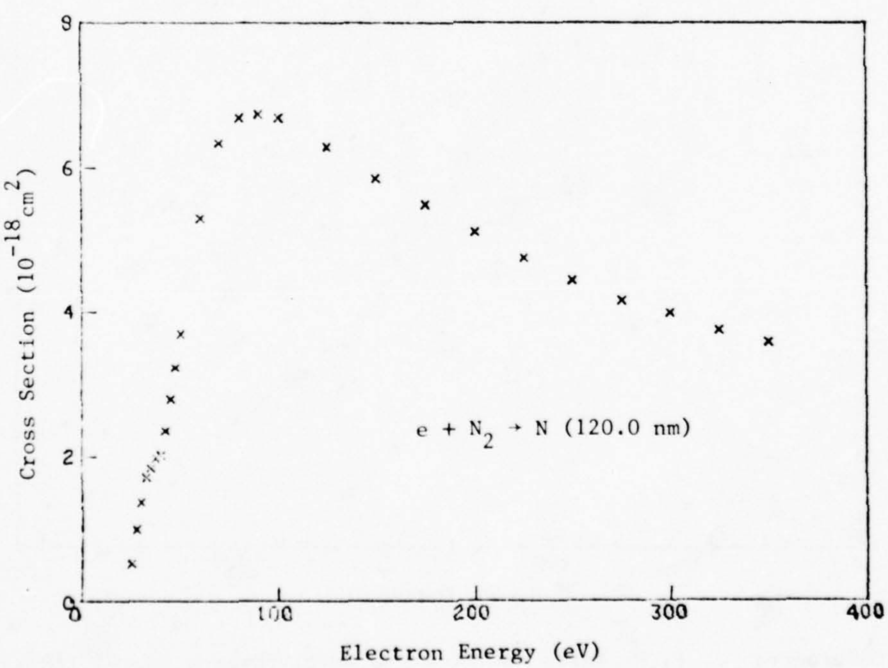
Reference: W. Sroka, Z. Naturforsch. 24a, 398 (1969)

Tabular and Graphical Data C-3.4d. Cross section for electron impact dissociation of N_2 to form excited fragments.

$e + N_2 \rightarrow N$ (120.0 nm)

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
25.0	0.530	47.5	3.22	175	5.49
27.5	1.00	50.0	3.69	200	5.11
30.0	1.37	60.0	5.30	225	4.75
32.5	1.71	70.0	6.35	250	4.43
35.0	1.84	80.0	6.70	275	4.15
37.5	1.97	90.0	6.75	300	3.98
40.0	2.01	100	6.70	325	3.74
42.5	2.35	125	6.30	350	3.57
45.0	2.78	150	5.87		

Cont. Next Column   Cont. Next Column

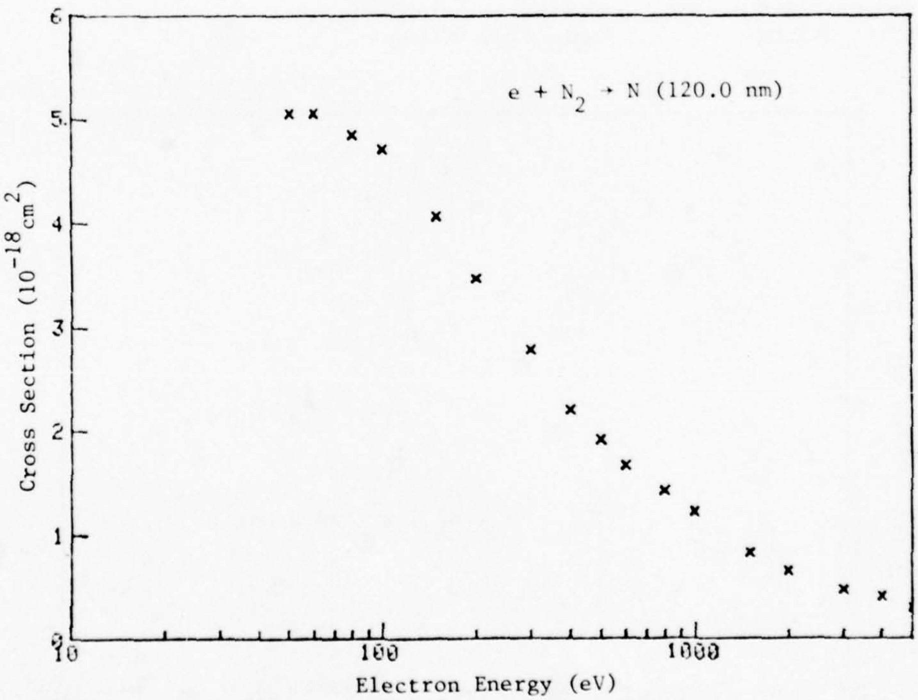


Reference: Mumma, M.J., Zipf, E.C., J. Chem. Phys. 55, 5582 (1971)

Tabular and Graphical Data C-3.4d. Cross sections for electron impact dissociation of N_2 to form excited fragments (Concluded).

$e + N_2 \rightarrow N$ (120.0 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
50	5.06	300	2.78	1500	0.830
60	5.06	400	2.20	2000	0.650
80	4.86	500	1.91	3000	0.470
100	4.72	600	1.66	4000	0.400
150	4.07	800	1.42	5000	0.300
200	3.47	1000	1.22		
Cont. Next Column		Cont. Next Column			



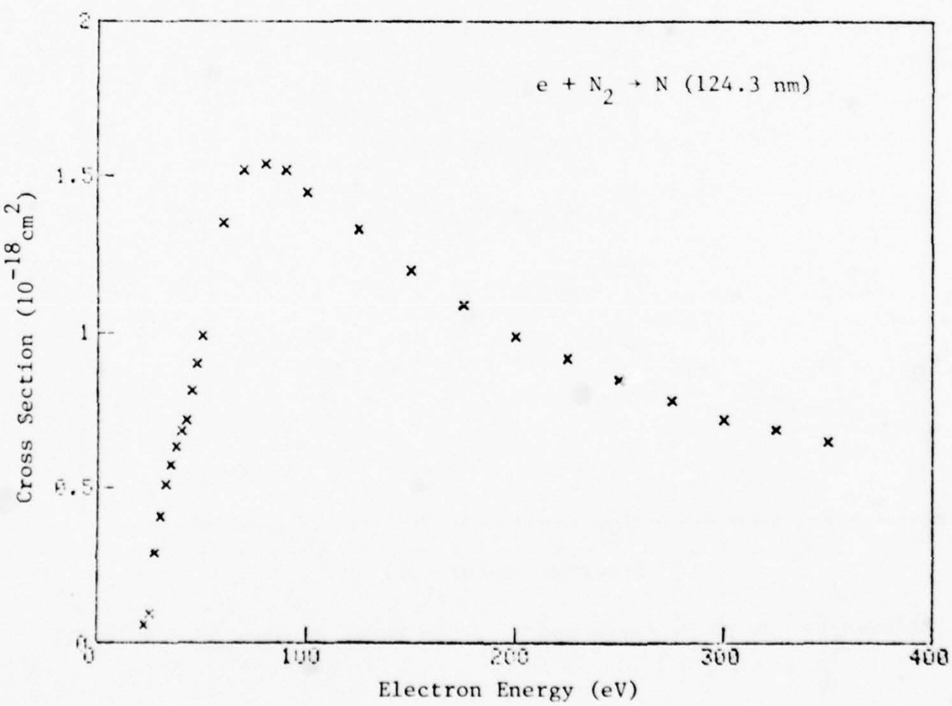
Reference: J. F. M. Aarts and F. J. de Heer, Physica 52, 45 (1971)

Tabular and Graphical Data C-3.4e. Cross sections for electron impact dissociation of N_2 to form excited fragments.

$e + N_2 \rightarrow N$ (124.3 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
22.5	0.0580	47.5	0.899	200	0.990
25.0	0.0940	50.0	0.990	225	0.920
27.5	0.290	60.0	1.35	250	0.850
30.0	0.406	70.0	1.52	275	0.780
32.5	0.508	80.0	1.54	300	0.720
35.0	0.573	90.0	1.52	325	0.690
37.5	0.630	100	1.45	350	0.650
40.0	0.681	125	1.33		
42.5	0.718	150	1.20		
45.0	0.812	175	1.09		

Cont. Next Column   Cont. Next Column



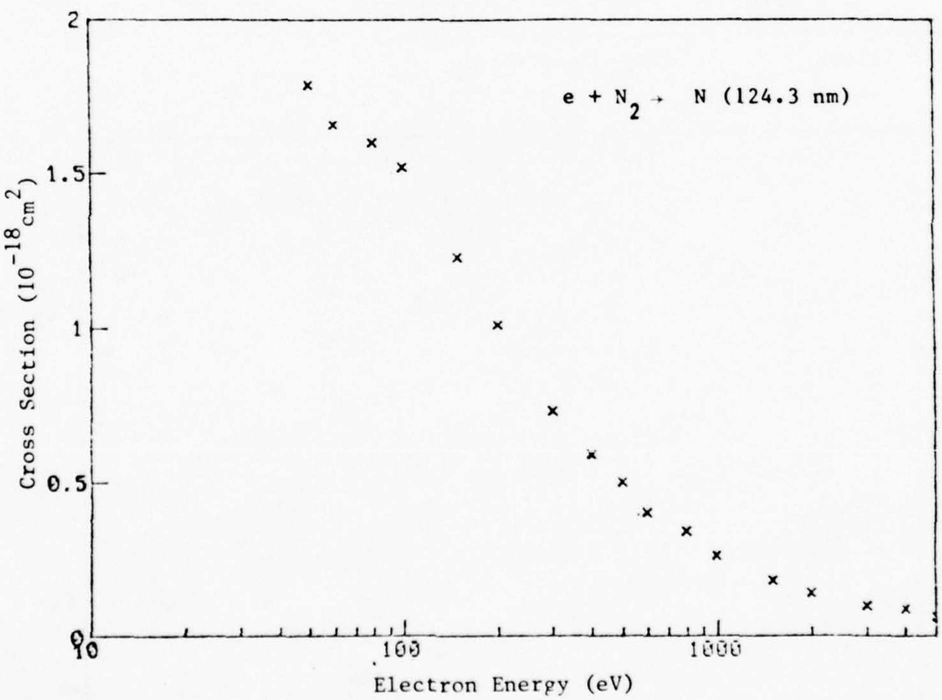
Reference: M. J. Mumma, E. C. Zipf, J. Chem. Phys. 55 (1971)

Tabular and Graphical Data C-3.4e. Cross sections for electron impact dissociation of N_2 to form excited fragments (Concluded).

$e + N_2 \rightarrow N$ (124.3 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
50	1.79	300	0.730	1500	0.181
60	1.66	400	0.590	2000	0.136
80	1.60	500	0.500	3000	0.0960
100	1.52	600	0.400	4000	0.0860
150	1.23	800	0.340	5000	0.0630
200	1.01	1000	0.260		

Cont. Next Column   Cont. Next Column



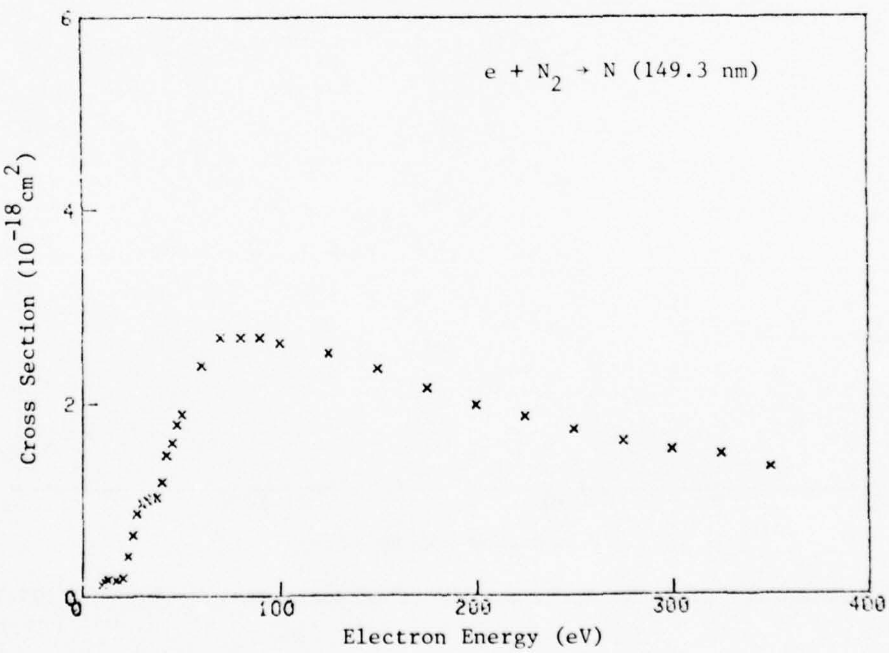
Reference: J. F. M. Aarts and F. J. de Heer, Physica 52, 45 (1971)

Tabular and Graphical Data C-3.4f. Cross sections for electron impact dissociation of N_2 to form excited fragments.

$e + N_2 \rightarrow N$ (149.3 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
10.00	0.120	35.0	1.02	125	2.51
11.2	0.150	37.5	1.03	150	2.35
12.5	0.180	40.0	1.19	175	2.15
14.0	0.170	42.5	1.47	200	1.98
15.8	0.170	45.0	1.59	225	1.86
17.8	0.165	47.5	1.79	250	1.73
20.0	0.196	50.0	1.89	275	1.60
22.5	0.419	60.0	2.39	300	1.52
25.0	0.634	70.0	2.68	325	1.47
27.5	0.851	80.0	2.68	350	1.33
30.0	0.956	90.0	2.68		
32.5	1.00	100	2.62		

Cont. Next Column   Cont. Next Column



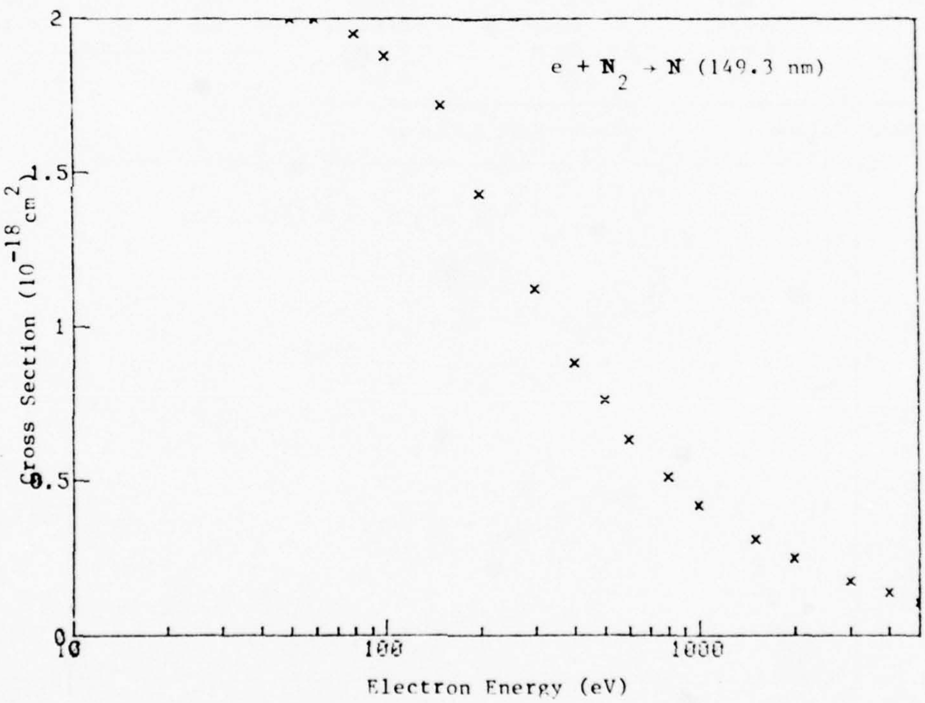
Reference: M. J. Mumma, E. C. Zipf, J. Chem. Phys. 55, 5582 (1971)

Tabular and Graphical Data C-3.4f. Cross sections for electron impact dissociation of N_2 to give excited fragments (Concluded).

$e + N_2 \rightarrow N$ (149.3 nm)

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
50	2.00	300	1.12	1500	0.310
60	2.00	400	0.880	2000	0.250
80	1.95	500	0.760	3000	0.177
100	1.88	600	0.630	4000	0.137
150	1.72	800	0.510	5000	0.107
200	1.43	1000	0.420		

Cont. Next Column Cont. Next Column

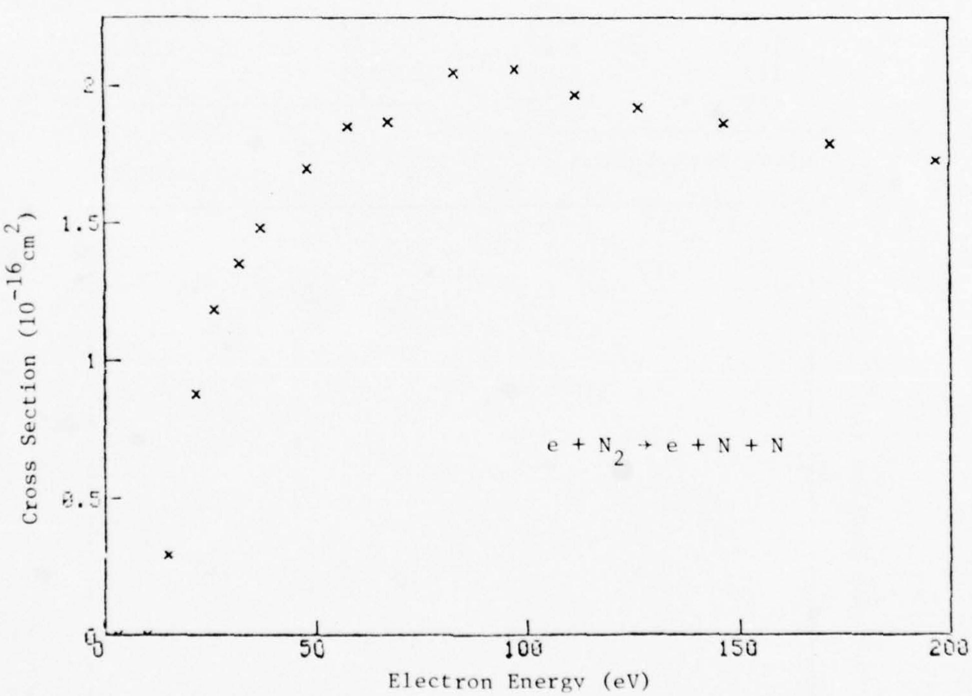


Reference: J. F. M. Aarts and F. J. de Heer, Physica 52, 45 (1971)

Tabular and Graphical Data C-3.5. Cross sections for electron impact dissociation of N_2.

$$e + N_2 \rightarrow e + N + N$$

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
3.10	0	36.5	1.48	112	1.97
10.1	0	47.9	1.70	126	1.92
14.8	0.294	57.5	1.85	147	1.87
21.3	0.878	67.1	1.87	172	1.79
25.6	1.19	82.9	2.05	197	1.73
31.3	1.35	97.4	2.06		
Cont. Next Column		Cont. Next Column			



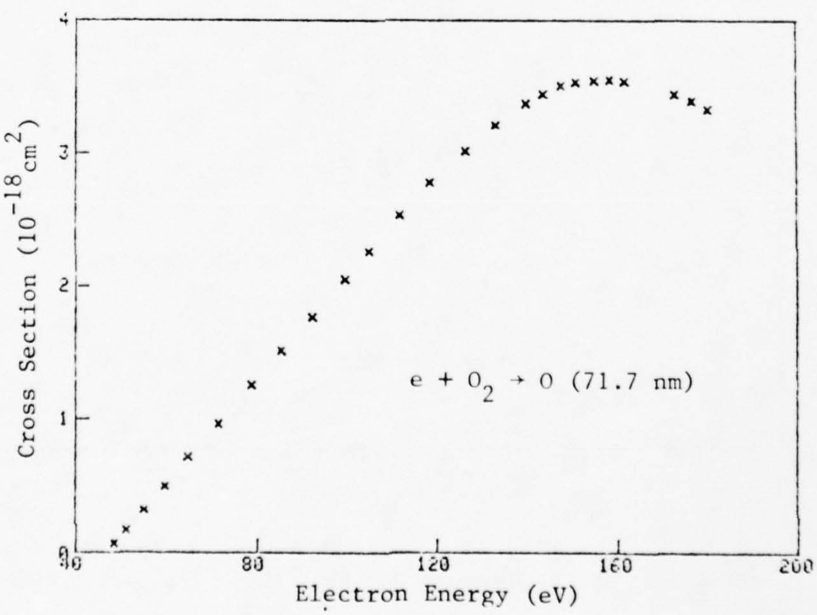
Reference: H. F. Winters, J. Chem. Phys. 44, 1472 (1966)

Tabular and Graphical Data C-3.6a. Cross sections for electron impact dissociation of O_2 to form excited fragments.

$$e + O_2 \rightarrow O\ (71.7\ \text{nm})$$

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
48.3	0.0626	127	3.02
51.0	0.170	133	3.22
55.1	0.318	140	3.38
59.7	0.490	144	3.45
64.8	0.710	148	3.51
71.6	0.962	151	3.54
79.0	1.25	155	3.55
85.5	1.51	159	3.56
92.4	1.77	162	3.55
99.6	2.05	173	3.45
105	2.27	177	3.40
112	2.54	180	3.33
119	2.78		

Cont. Next Column



Reference: W. Sroka, Z. Naturforsch. 23a, 2004 (1968)

Tabular Data C-3.6b. Cross sections for electron impact dissociation of O_2 to form excited fragments.

$e + O_2 \rightarrow O$ (83.3 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
37.5	0.0681	97.5	7.48
38.6	0.180	102	7.76
41.3	0.589	108	8.08
44.9	1.19	114	8.30
48.8	1.80	119	8.51
52.5	2.36	126	8.71
55.8	2.85	132	8.87
58.9	3.31	139	8.98
67.1	4.55	146	9.05
71.0	5.07	160	9.02
75.1	5.54	167	8.95
78.9	5.96	174	8.85
82.4	6.33	180	8.74
86.0	6.65	188	8.54
89.3	6.92		
93.0	7.19		

Cont. Next Column

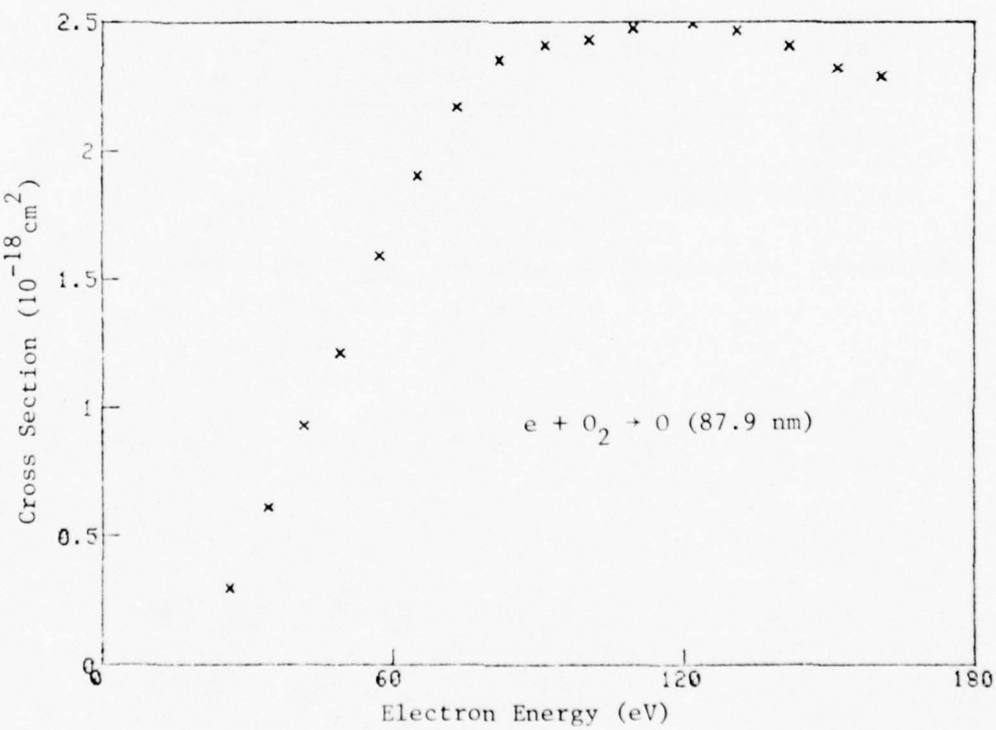
Reference: W. Sroka, Z. Naturforsch. 23a, 2004 (1968)

Tabular and Graphical Data C-3.6c. Cross sections for electron impact dissociation of O_2 to form excited fragments.

$e + O_2 \rightarrow O$ (87.9 nm)

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
26.1	0.293	100	2.43
33.9	0.611	110	2.47
41.5	0.931	122	2.50
48.9	1.22	131	2.47
57.2	1.60	142	2.41
65.1	1.91	152	2.33
73.4	2.18	161	2.29
81.8	2.35		
91.4	2.41		

Cont. Next Column



Reference: W. Sroka, Z. Naturforsch 23a, 2004 (1968)

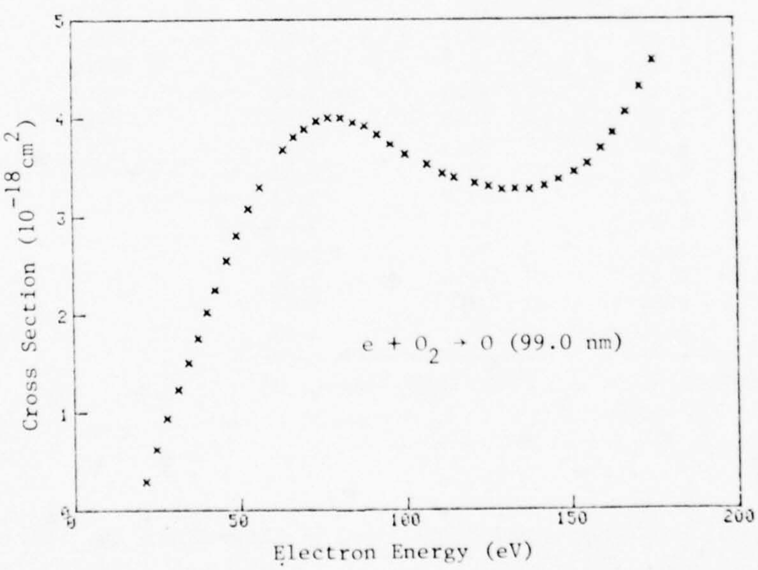
Tabular and Graphical Data C-3.6d. Cross sections for electron impact dissociation of O_2 to form excited fragments.

$e + O_2 \rightarrow O$ (99.0 nm)

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
21.3	0.288	70.1	3.89	130	3.27
24.5	0.620	73.8	3.97	134	3.28
27.7	0.935	77.3	4.00	138	3.27
31.1	1.23	81.1	4.00	143	3.32
34.4	1.51	84.7	3.96	147	3.37
37.4	1.76	88.3	3.92	152	3.45
40.0	2.02	92.1	3.83	155	3.54
42.6	2.25	95.9	3.73	160	3.69
46.1	2.56	100	3.63	163	3.85
49.0	2.81	107	3.53	167	4.06
52.8	3.08	112	3.44	171	4.31
56.3	3.30	115	3.39	175	4.58
63.7	3.68	122	3.34		
66.7	3.81	126	3.31		

Cont. Next Column

Cont. Next Column



Reference: W. Sroka, Z. Naturforsch. 23a, 2004 (1968)

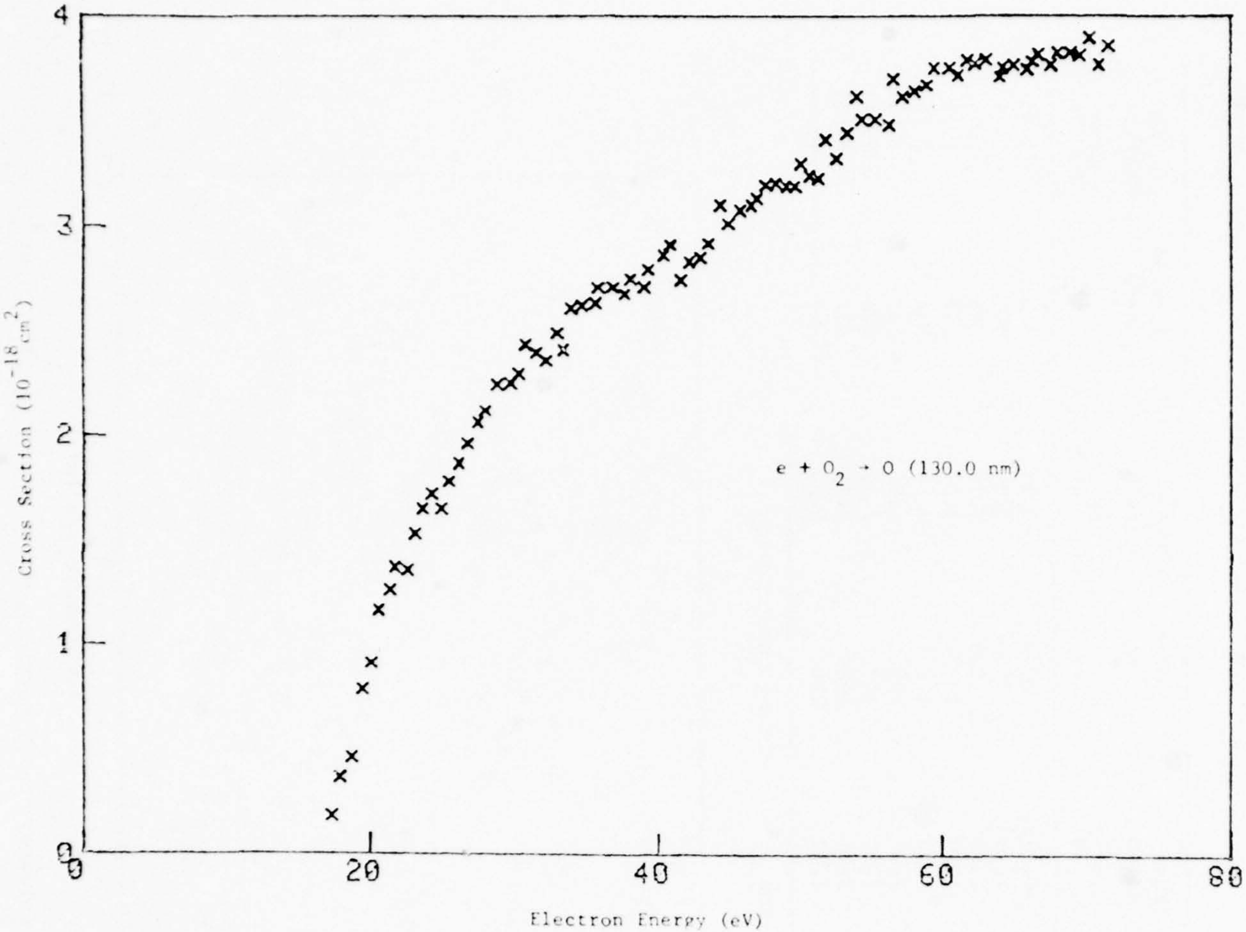
Tabular Data C-3.6e. Cross sections for electron impact dissociation of O_2 to form excited fragments.

$e + O_2 \rightarrow O$ (130.0 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
17.3	0.178	36.9	2.71	56.6	3.71
17.9	0.368	37.7	2.68	57.3	3.62
18.7	0.459	38.1	2.75	58.1	3.65
19.5	0.789	39.0	2.71	58.9	3.68
20.1	0.912	39.3	2.80	59.5	3.76
20.6	1.17	40.4	2.87	60.5	3.76
21.4	1.26	40.9	2.92	61.1	3.72
21.7	1.37	41.6	2.75	61.8	3.80
22.6	1.36	42.2	2.84	62.3	3.77
23.2	1.53	43.0	2.86	63.0	3.79
23.8	1.65	43.6	2.92	64.0	3.72
25.1	1.65	44.4	3.10	64.2	3.76
24.4	1.73	45.0	3.02	65.0	3.77
25.6	1.78	45.8	3.08	65.9	3.75
26.3	1.87	46.6	3.11	66.3	3.79
26.9	1.96	47.0	3.14	66.7	3.82
27.6	2.07	47.6	3.20	67.6	3.77
28.1	2.12	48.4	3.21	68.0	3.83
29.0	2.25	49.1	3.19	68.9	3.83
29.9	2.25	49.7	3.20	69.5	3.81
30.4	2.30	50.2	3.30	70.2	3.90
30.9	2.44	50.8	3.25	70.9	3.77
31.6	2.40	51.4	3.23	71.5	3.86
32.3	2.36	51.9	3.42		
33.0	2.49	52.7	3.33		
33.5	2.41	53.4	3.45		
34.0	2.61	54.1	3.62		
34.7	2.62	54.5	3.51		
35.7	2.64	55.4	3.51		
35.9	2.71	56.3	3.49		

Cont. Next Column   Cont. Next Column

Reference: M. J. Mumma and E. C. Zipf, J. Chem. Phys. 55, 1661 (1971)



Reference: M. J. Mumma and E. C. Zipf, J. Chem. Phys. 55, 1661 (1971)

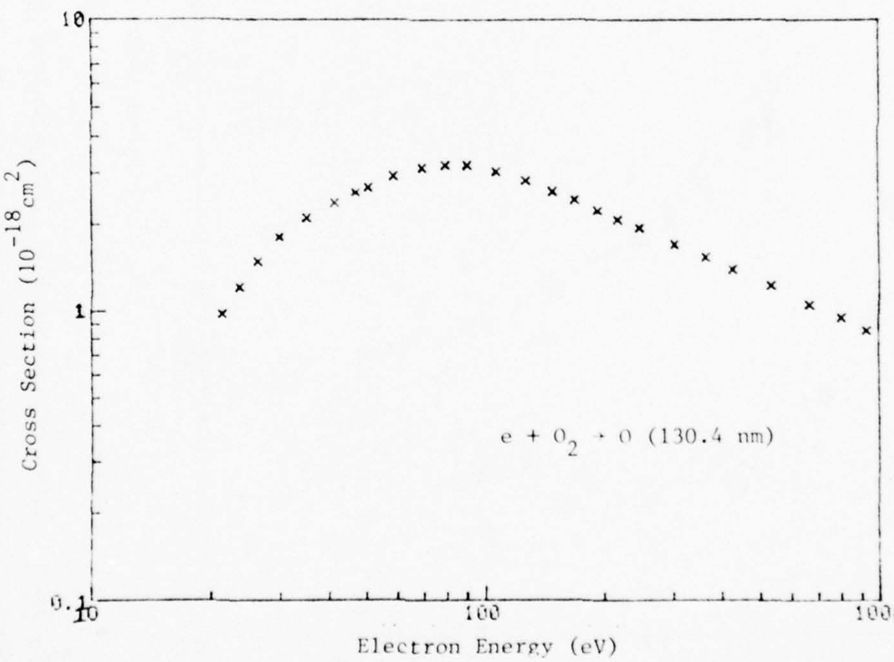
Graphical Data C-3.6e. Cross sections for electron impact dissociation of O_2 to form excited fragments. (Tabular data on the facing page.)

Tabular and Graphical Data C-3.6f. Cross sections for electron impact dissociation of O_2 to form excited fragments.

$e + O_2 \rightarrow O$ (130.4 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
21.4	0.976	69.3	3.12	248	1.95
23.5	1.20	79.5	3.20	305	1.71
26.3	1.48	90.3	3.19	365	1.54
29.8	1.80	107	3.04	427	1.39
35.1	2.10	127	2.82	533	1.22
41.3	2.37	149	2.60	667	1.05
46.9	2.57	169	2.43	806	0.947
50.6	2.68	194	2.24	931	0.853
58.6	2.92	218	2.09		

Cont. Next Column Cont. Next Column



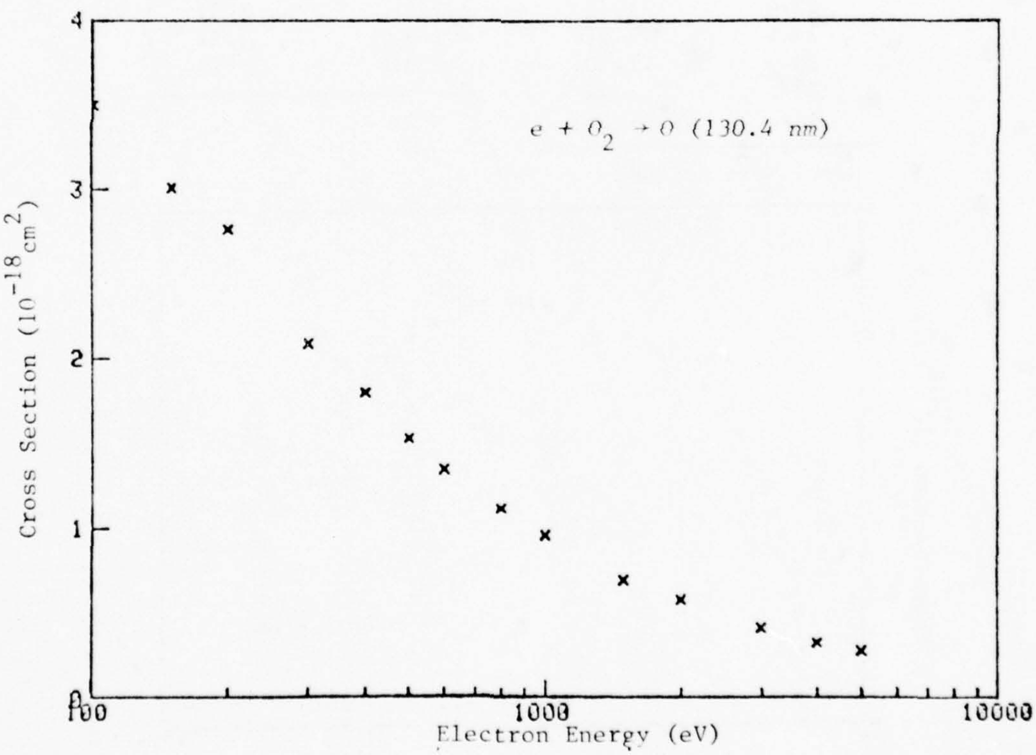
Reference: G. M. Lawrence, Phys. Rev. A 2, 397 (1970)

Tabular and Graphical Data C-3.6f. Cross sections for electron impact dissociation of O_2 to form excited fragments (Concluded).

$e + O_2 \rightarrow O$ (130.4 nm)

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
100	3.50	1000	0.955
150	3.01	1500	0.685
200	2.76	2000	0.570
300	2.08	3000	0.406
400	1.79	4000	0.318
500	1.52	5000	0.269
600	1.34		
800	1.11		

Cont. Next Column



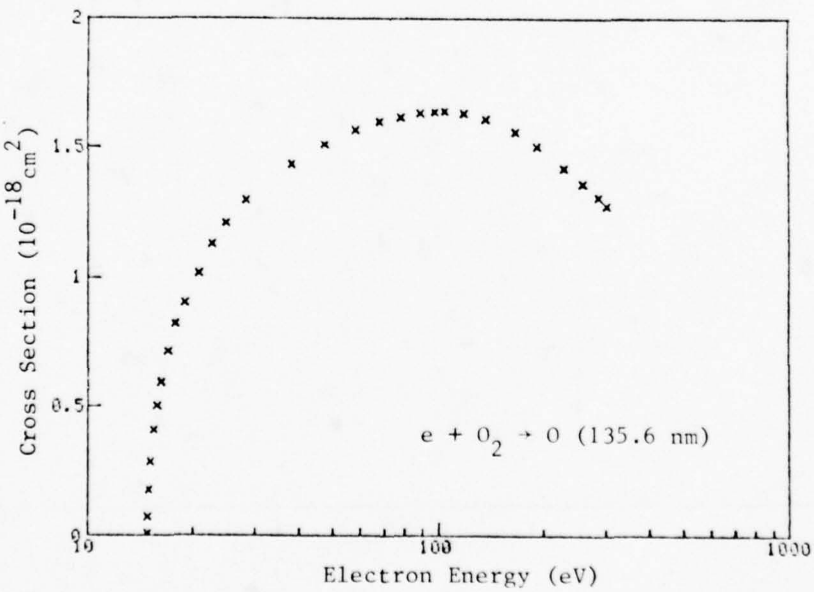
Reference: J. F. M. Aarts and F. J. de Heer, Physica 56, 294 (1971)

Tabular and Graphical Data C-3.6g. Cross sections for electron impact dissociation of O_2 to form excited fragments.

$e + O_2 \rightarrow O$ (135.6 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
14.8	0.00841	58.0	1.57
14.8	0.0724	68.0	1.60
14.9	0.172	78.2	1.62
15.1	0.281	89.0	1.63
15.4	0.405	97.8	1.64
15.7	0.501	105	1.64
16.1	0.593	119	1.64
17.0	0.712	138	1.61
17.8	0.818	168	1.56
19.0	0.904	193	1.51
20.8	1.02	230	1.43
22.6	1.13	260	1.37
24.8	1.21	288	1.31
28.3	1.30	303	1.28
38.1	1.44		
47.2	1.51		

Cont. Next Column



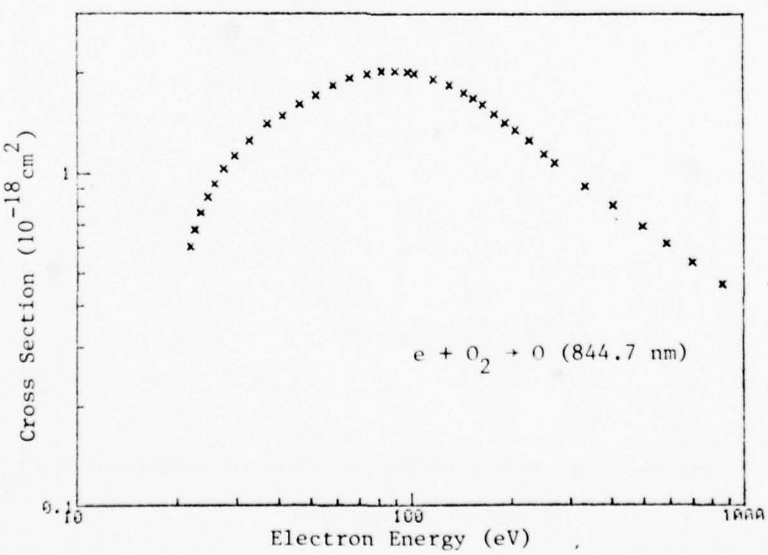
Reference: J. M. Ajello, J. Chem. Phys. 55, 3156 (1971)

Tabular and Graphical Data C-3.6h. Cross sections for electron impact dissociation of O_2 to form excited fragments.

$e + O_2 \rightarrow O$ (844.7 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
21.7	0.603	74.3	1.99	251	1.15
22.3	0.676	81.9	2.03	271	1.09
23.3	0.764	89.9	2.03	335	0.917
24.4	0.850	98.2	2.02	405	0.804
25.7	0.933	103	2.00	497	0.693
27.4	1.03	118	1.91	588	0.616
29.6	1.13	131	1.85	701	0.540
32.7	1.26	145	1.75	860	0.464
37.0	1.41	155	1.68		
41.0	1.49	165	1.61		
46.4	1.61	178	1.51		
51.9	1.72	193	1.43		
58.4	1.83	206	1.35		
65.6	1.93	227	1.26		

Cont. Next Column   Cont. Next Column



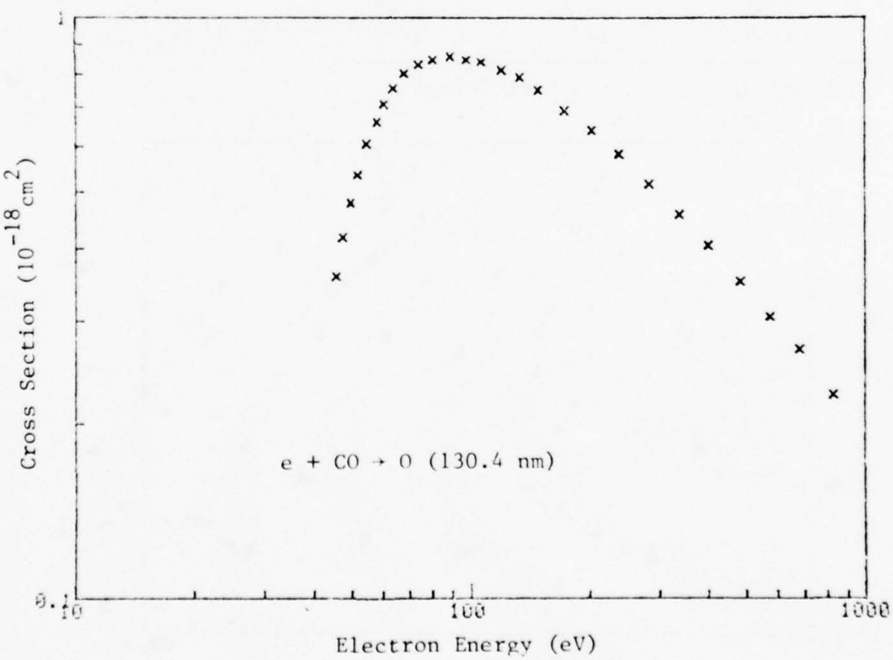
Reference: G. M. Lawrence, Phys. Rev. A 2, 397 (1970)

Tabular and Graphical Data C-3.7a. Cross sections for electron impact dissociation of CO to form excited fragments.

$e + CO \rightarrow O$ (130.4 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
45.6	0.357	80.3	0.846	284	0.518
47.3	0.418	88.8	0.857	339	0.459
49.5	0.479	97.5	0.846	402	0.406
51.5	0.536	107	0.840	485	0.351
54.5	0.607	120	0.814	575	0.305
57.8	0.662	134	0.790	681	0.269
60.3	0.709	149	0.750	832	0.224
63.6	0.755	173	0.693		
67.7	0.802	203	0.640		
73.7	0.831	237	0.582		

Cont. Next Column   Cont. Next Column



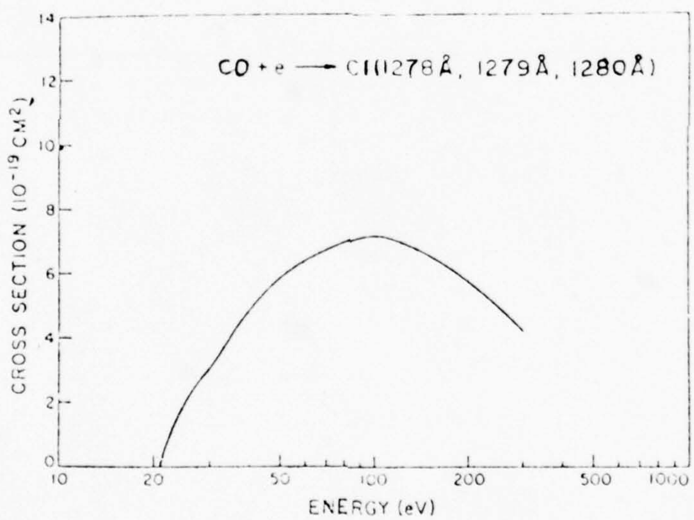
Reference: G. M. Lawrence, Phys. Rev. A 2, 397 (1970)

Tabular and Graphical Data C-3.7b. Cross sections for electron impact dissociation of CO to form excited fragments.

$e + CO \rightarrow C$ (127.8/128.0 nm)

Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$
21.0	0.0201	41.9	5.08	139	6.65
21.5	0.407	48.8	5.76	155	6.40
22.6	0.971	55.2	6.16	176	6.07
24.1	1.63	65.7	6.58	202	5.64
27.1	2.52	78.0	6.91	228	5.20
29.4	2.94	96.1	7.14	255	4.75
31.1	3.27	100	7.12	293	4.17
34.2	3.88	113	7.03		
37.3	4.44	126	6.86		

Cont. Next Column   Cont. Next Column



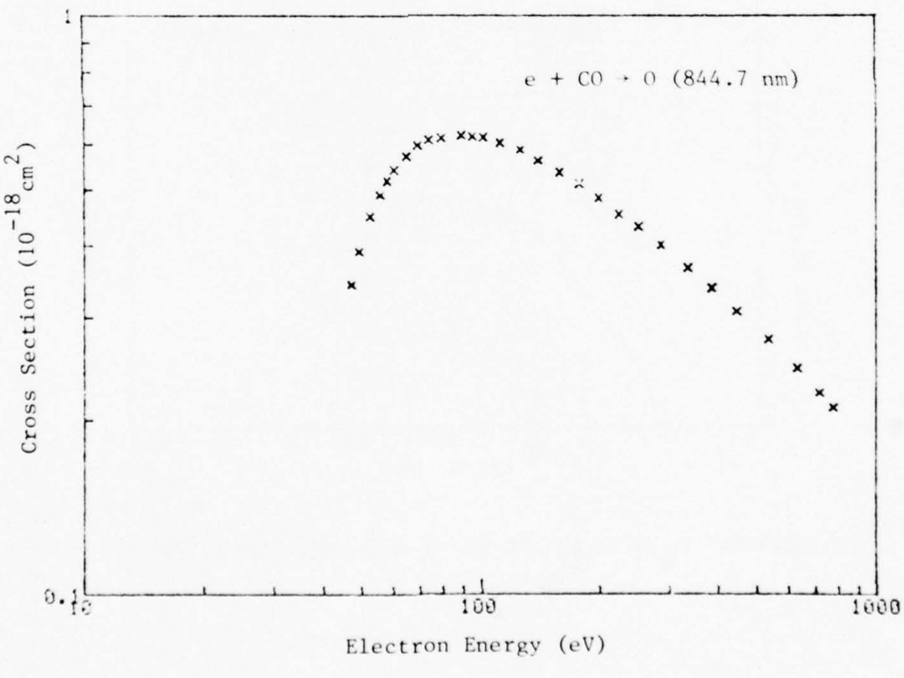
Reference: J. M. Ajello, J. Chem. Phys. <u>55</u>, 3158 (1971)

Tabular and Graphical Data C-3.7c. Cross sections for electron impact dissociation of CO to form excited fragments.

e + CO → O (844.7 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
47.1	0.343	89.0	0.622	251	0.432
49.1	0.391	95.0	0.619	287	0.402
52.5	0.450	102	0.617	337	0.366
55.6	0.492	112	0.605	387	0.338
57.8	0.518	126	0.588	446	0.307
60.1	0.542	140	0.562	535	0.275
64.7	0.574	158	0.537	634	0.246
69.0	0.597	178	0.513	721	0.223
73.6	0.611	200	0.484	780	0.210
79.2	0.616	225	0.453		

Cont. Next Column　　Cont. Next Column



Reference: G. M. Lawrence, Phys. Rev. A 2, 397 (1970)

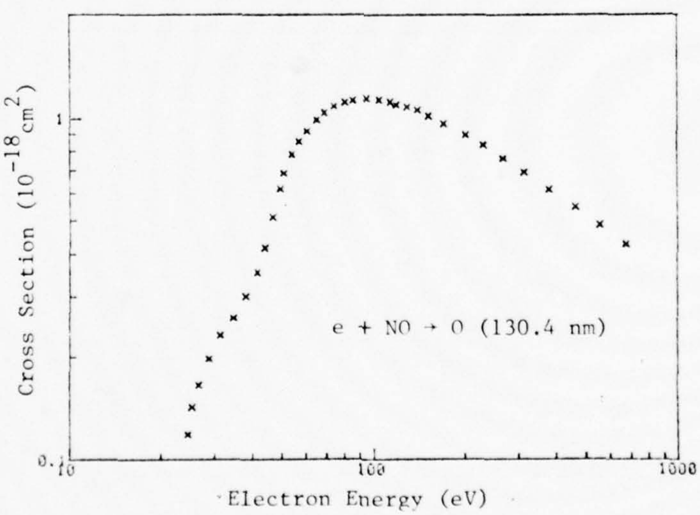
Tabular and Graphical Data C-3.8a. Cross sections for electron impact dissociation of NO to form excited fragments.

$e + NO \rightarrow O\ (130.4\ nm)$

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
24.4	0.118	60.6	0.919	202	0.897
25.3	0.142	65.0	0.992	231	0.835
26.7	0.164	68.7	1.04	269	0.762
28.8	0.197	74.1	1.09	315	0.694
31.3	0.231	80.4	1.12	381	0.619
34.7	0.261	85.1	1.14	463	0.548
38.1	0.300	94.8	1.15	557	0.486
41.5	0.355	104	1.14	677	0.428
44.0	0.417	114	1.13		
46.6	0.513	119	1.11		
49.3	0.621	129	1.09		
50.7	0.689	140	1.07		
53.9	0.784	152	1.02		
57.0	0.856	171	0.971		

Cont. Next Column

Cont. Next Column



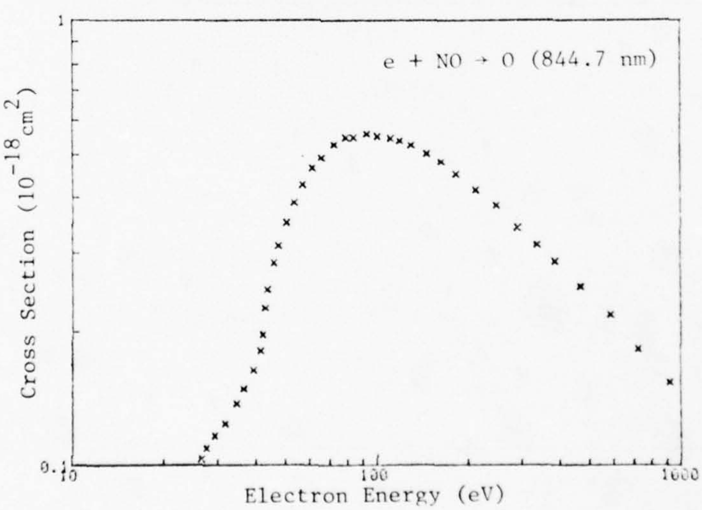
Reference: G. M. Lawrence, Phys. Rev. A 2, 397 (1970)

Tabular and Graphical Data C-3.8b. Cross sections for electron impact dissociation of NO to form excited fragments.

e + NO → O (844.7 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
26.5	0.103	53.3	0.388	182	0.450
27.5	0.109	56.7	0.426	212	0.415
29.3	0.116	61.0	0.463	247	0.382
31.6	0.124	65.5	0.491	292	0.341
34.5	0.137	72.2	0.528	338	0.313
36.5	0.148	79.2	0.547	387	0.287
39.2	0.163	83.9	0.548	469	0.252
41.4	0.181	93.0	0.558	587	0.217
42.0	0.196	101	0.551	726	0.182
42.7	0.225	112	0.544	920	0.153
43.3	0.248	120	0.538		
45.7	0.285	130	0.526		
47.4	0.311	146	0.502		
50.2	0.350	164	0.480		

Cont. Next Column   Cont. Next Column



Reference: G. M. Lawrence, Phys. Rev. A 2, 397 (1970)

Tabular Data C-3.8c. Cross sections for electron impact dissociation of NO to form excited fragments.

$e + NO \rightarrow N$ (120.0 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
18.3	0.0477	53.0	3.58	132	4.39
19.5	0.288	56.5	3.97	144	4.26
22.2	0.670	61.3	4.35	156	4.15
25.4	1.24	68.3	4.61	168	4.03
29.5	1.68	76.3	4.77	181	3.91
33.4	1.91	85.4	4.84	195	3.79
39.7	2.17	95.2	4.81	210	3.68
45.1	2.58	107	4.71	224	3.59
49.1	3.14	118	4.56	235	3.51
Cont. Next Column		Cont. Next Column			

Tabular Data C-3.8d. Cross sections for electron impact dissociation of NO to form excited fragments.

$e + NO \rightarrow N$ (149.3 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
19.7	0.0380	54.4	1.19	149	1.31
22.1	0.155	64.2	1.38	163	1.27
25.8	0.380	75.4	1.50	175	1.24
33.4	0.778	86.1	1.52	188	1.19
37.2	0.791	97.8	1.51	200	1.16
40.8	0.812	110	1.49	214	1.14
45.9	0.945	121	1.45	227	1.09
46.5	0.976	134	1.38	236	1.09
Cont. Next Column		Cont. Next Column			

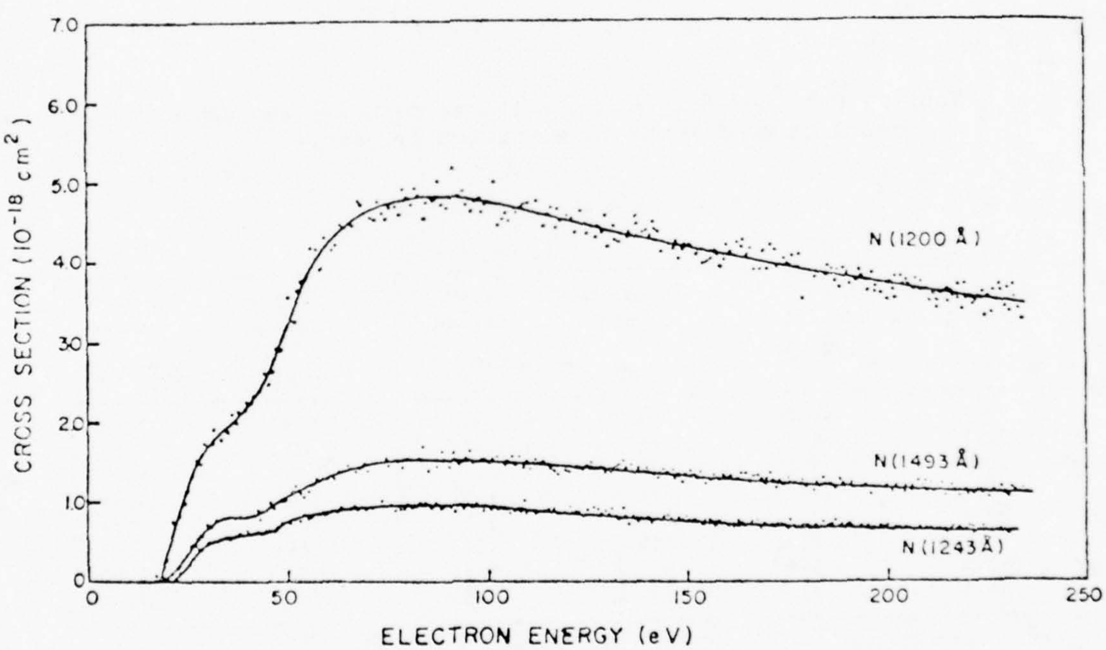
Reference: J. E. Mentall and H. D. Morgan, J. Chem. Phys. 56, 2271 (1972)

Tabular and Graphical Data C-3.8e. Cross sections for electron impact dissociation of NO to form excited fragments.

e + NO → N (124.3 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
22.0	0.029	55.8	0.81	164	0.70
24.0	0.14	64.9	0.90	178	0.67
27.2	0.32	74.3	0.94	196	0.66
30.5	0.48	86.4	0.94	210	0.66
37.2	0.57	101	0.92	225	0.62
44.2	0.62	116	0.85	233	0.63
47.0	0.64	131	0.80		
49.7	0.73	146	0.75		

Cont. Next Column   Cont. Next Column



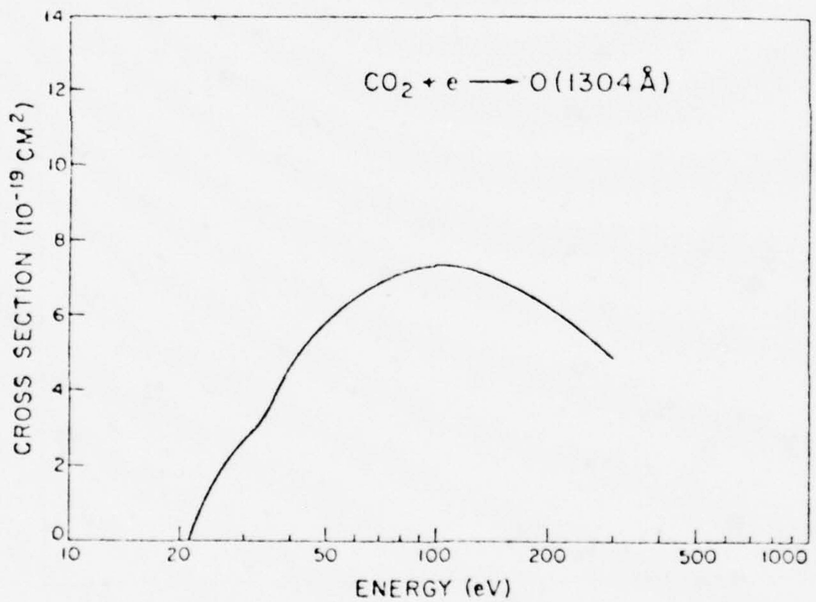
Reference: J. E. Mentall and H. D. Morgan, J. Chem. Phys. 56, 2271 (1972)

Tabular and Graphical Data C-3.9a. Cross sections for electron impact dissociation of CO_2 to form excited fragments.

$e + CO_2 \rightarrow O$ (130.4 nm)

Electron Energy eV	Cross Section 10^{-19} cm^2	Electron Energy eV	Cross Section 10^{-19} cm^2	Electron Energy eV	Cross Section 10^{-19} cm^2
21.1	0.0238	43.4	5.23	138	7.08
22.4	0.713	47.2	5.65	156	6.83
24.8	1.64	53.7	6.16	176	6.57
29.5	2.66	63.6	6.68	202	6.21
31.0	2.90	73.6	7.04	224	5.92
32.6	3.13	81.3	7.21	242	5.69
34.1	3.43	89.7	7.30	265	5.34
35.7	3.77	97.8	7.36	296	4.93
38.1	4.31	107	7.35		
40.2	4.70	120	7.25		

Cont. Next Column   Cont. Next Column



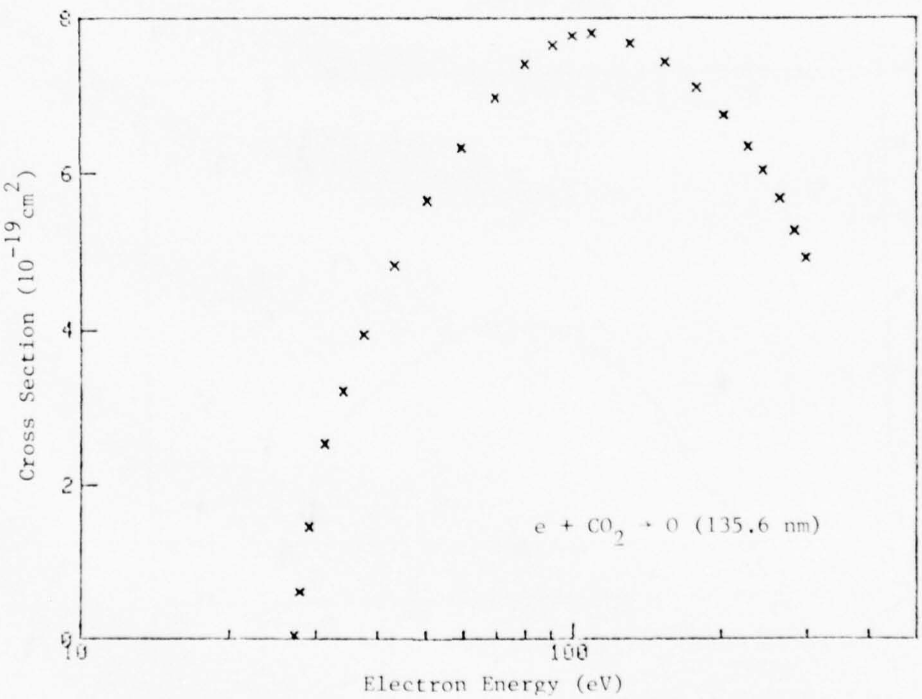
Reference: J. M. Ajello, J. Chem. Phys. 55, 3169 (1971)

Tabular and Graphical Data C-3.9b. Cross sections for electron impact dissociation of CO_2 to form excited fragments.

$e + CO_2 \rightarrow O$ (135.6 nm)

Electron Energy eV	Cross Section $10^{-19}cm^2$	Electron Energy eV	Cross Section $10^{-19}cm^2$	Electron Energy eV	Cross Section $10^{-19}cm^2$
27.1	0.0394	59.1	6.33	178	7.10
27.7	0.612	69.4	6.98	203	6.75
28.9	1.46	79.8	7.41	227	6.35
31.2	2.53	90.9	7.65	244	6.05
33.9	3.21	99.9	7.78	264	5.68
37.5	3.95	109	7.81	283	5.26
43.2	4.83	130	7.69	299	4.91
50.5	5.66	154	7.44		

Cont. Next Column   Cont. Next Column



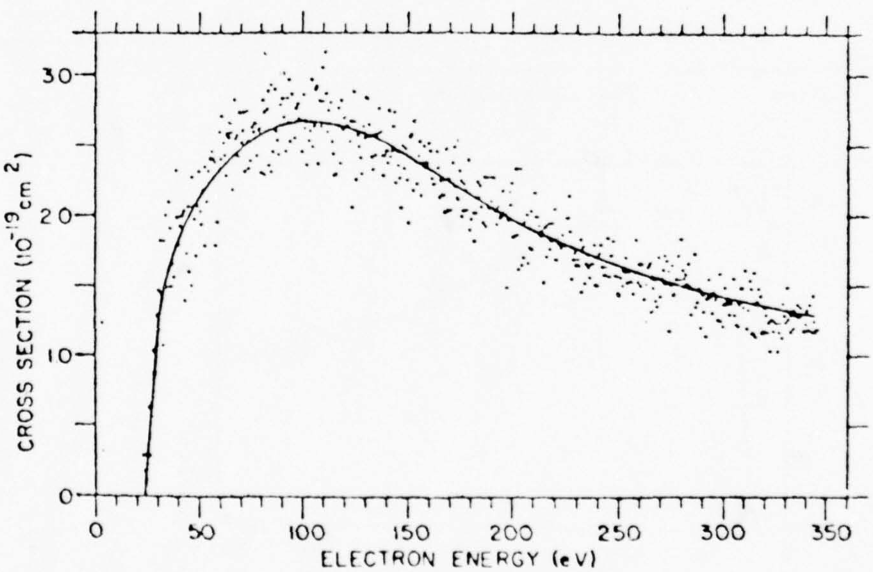
Reference: J. M. Ajello, J. Chem. Phys. 55, 3169 (1971)

Tabular and Graphical Data C-3.9c. Cross sections for electron impact dissociation of CO_2 to form excited fragments.

$$e + CO_2 \rightarrow C\ (132.9\ \text{nm})$$

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
23.9	0.0014	67.7	0.25	211	0.19
25.0	0.024	80.7	0.26	233	0.17
26.7	0.059	93.7	0.26	257	0.16
28.7	0.099	105	0.26	277	0.15
30.5	0.13	120	0.26	300	0.14
34.2	0.16	135	0.25	327	0.13
39.7	0.18	149	0.24	344	0.13
46.7	0.21	167	0.22		
55.9	0.23	186	0.21		

Cont. Next Column   Cont. Next Column



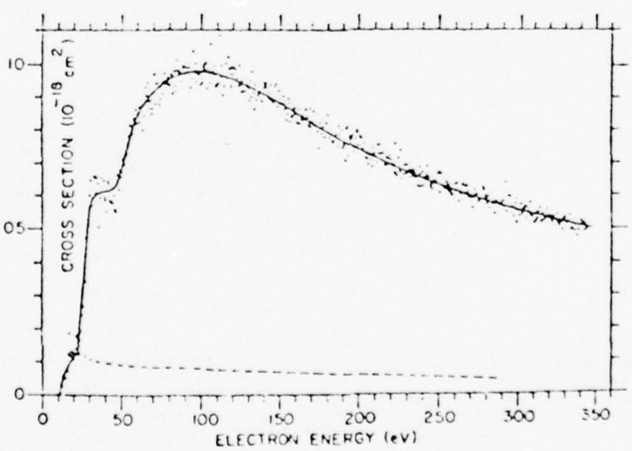
Reference: M. J. Mumma, E. J. Stone, W. L. Borst, and F. C. Zipf, J. Chem. Phys. 57, 68 (1972)

Tabular and Graphical Data C-3.9d. Cross sections for electron impact dissociation of CO_2 to form excited fragments.

$e + CO_2 \rightarrow C$ (156.1 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
10.8	0.0035	37.4	0.62	131	0.93
12.1	0.027	41.6	0.62	144	0.90
13.3	0.050	45.1	0.63	155	0.87
15.2	0.072	46.9	0.63	171	0.83
17.4	0.091	49.2	0.66	184	0.79
19.1	0.10	51.7	0.69	198	0.75
21.9	0.12	55.1	0.75	218	0.70
23.3	0.14	59.6	0.82	234	0.66
24.2	0.20	63.8	0.88	251	0.63
25.2	0.27	69.1	0.91	268	0.60
27.4	0.37	73.7	0.93	285	0.58
29.2	0.49	80.1	0.95	303	0.55
30.2	0.56	87.0	0.97	325	0.52
30.9	0.58	95.4	0.98	336	0.51
32.4	0.60	106	0.97	348	0.50
34.3	0.61	120	0.95		

Cont. Next Column   Cont. Next Column



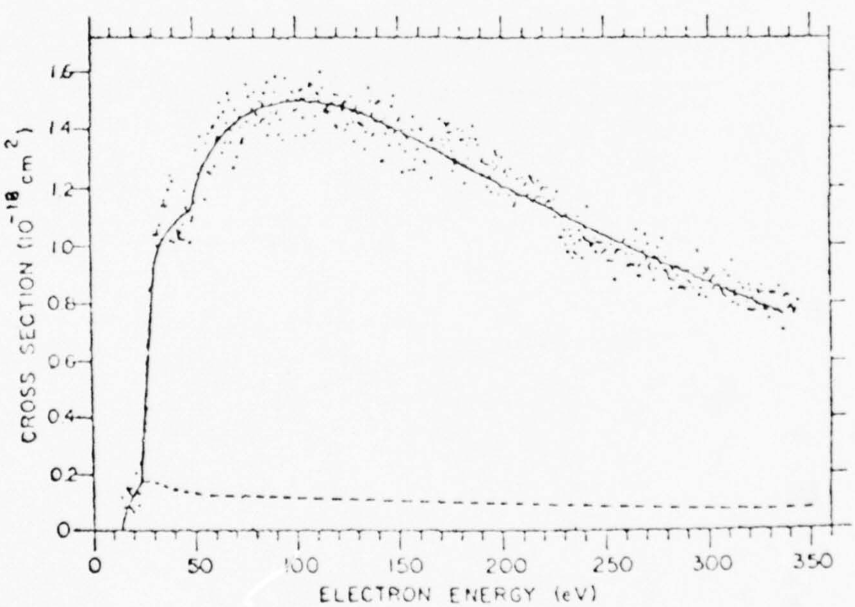
Reference: M. J. Mumma, E. J. Stone, W. L. Borst, and E. C. Zipf, J. Chem. Phys. 57, 68 (1972)

Tabular and Graphical Data C-3.9e. Cross sections for electron impact dissociation of CO_2 to form excited fragments.

$e + CO_2 \rightarrow C\ (165.7\ nm)$

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
14.1	0.00012	45.1	1.1	144	1.4
15.7	0.058	47.9	1.1	159	1.4
19.0	0.11	51.4	1.2	178	1.3
21.7	0.14	57.6	1.3	193	1.2
23.6	0.17	64.6	1.4	220	1.1
25.5	0.39	73.6	1.4	242	1.0
28.6	0.76	84.1	1.5	264	0.97
29.9	0.91	94.9	1.5	291	0.88
31.8	0.96	107	1.5	309	0.83
34.7	1.0	120	1.5	335	0.75
40.1	1.1	133	1.4		

Cont. Next Column   Cont. Next Column



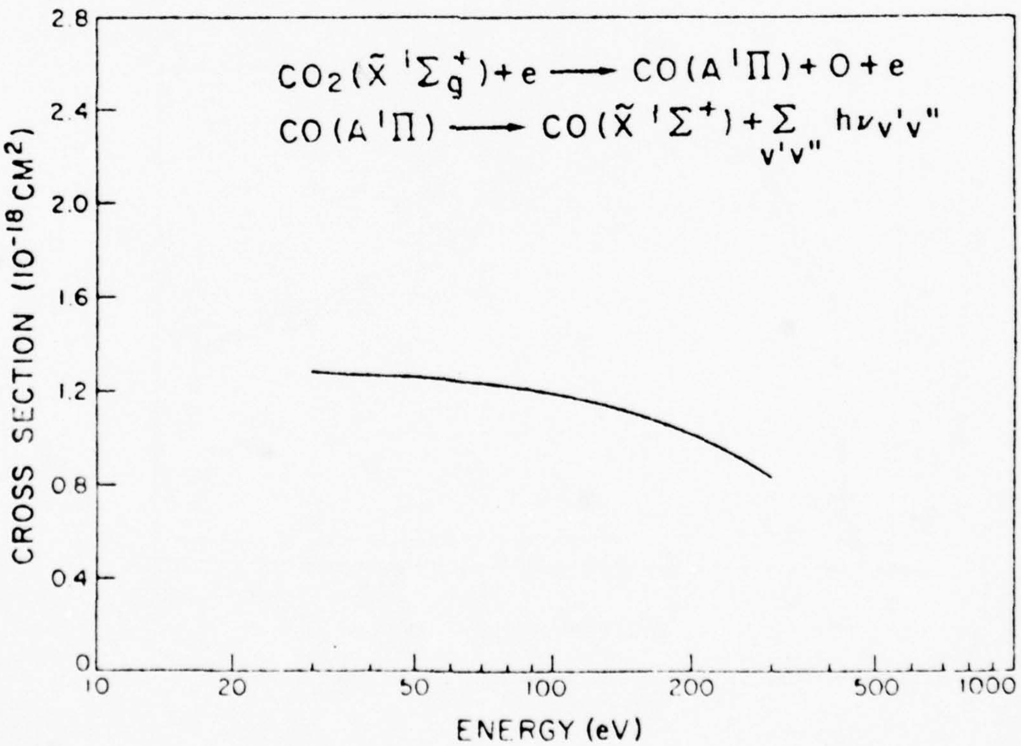
Reference: M. J. Mumma, F. J. Stone, W. L. Borst, and F. C. Zipf, J. Chem. Phys. 57, 68 (1972)

Tabular and Graphical Data C-3.9f. Cross sections for electron impact dissociation of CO_2 to form excited fragments.

$$e + CO_2 \rightarrow CO\ (A - X)$$

Electron Energy eV	Cross Section 10^{-18} cm^2	Electron Energy eV	Cross Section 10^{-18} cm^2
30.4	1.28	118	1.17
33.6	1.27	144	1.13
38.7	1.27	172	1.08
45.5	1.26	213	1.02
52.3	1.26	256	0.940
65.2	1.24	290	0.878
82.0	1.22	322	0.825
98.5	1.20		

Cont. Next Column



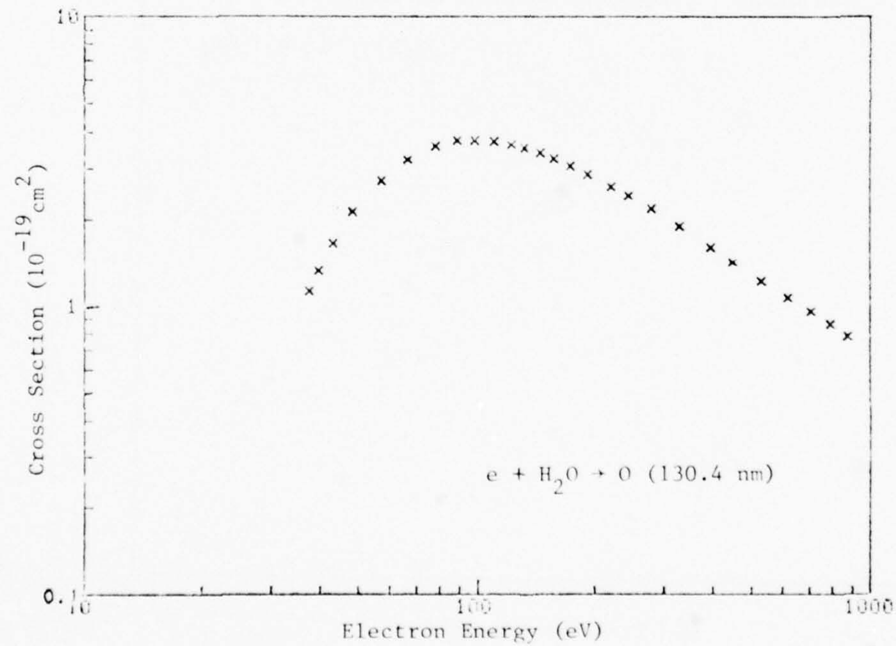
Reference: J. M. Ajello, J. Chem. Phys. 55, 3158 (1971)

Tabular and Graphical Data C-3.10a. Cross sections for electron impact dissociation of H_2O to form excited fragments.

$e + H_2O \rightarrow O$ (130.4 nm)

Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$
37.5	1.13	123	3.63	396	1.61
39.4	1.33	132	3.54	450	1.43
43.0	1.65	145	3.41	531	1.23
48.0	2.13	157	3.26	621	1.08
57.0	2.72	173	3.08	709	0.960
66.4	3.23	192	2.88	795	0.866
77.8	3.59	221	2.63	880	0.786
88.7	3.75	244	2.44		
98.4	3.77	279	2.20		
110	3.74	330	1.91		

Cont. Next Column   Cont. Next Column



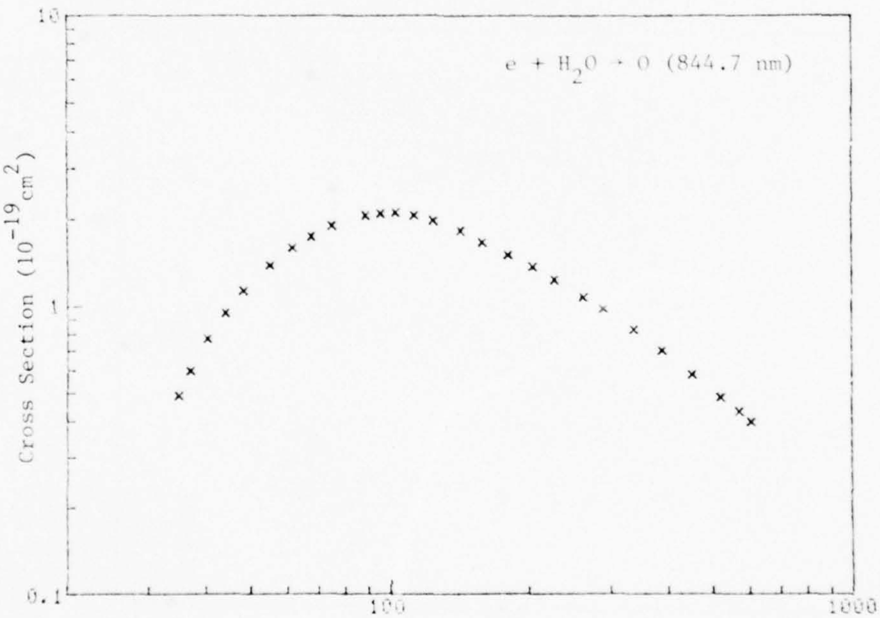
Reference: G. M. Lawrence, Phys. Rev. A 2, 397 (1970)

Tabular and Graphical Data C-3.10b. Cross sections for electron impact dissociation of H_2O to form excited fragments.

$e + H_2O \rightarrow O$ (844.7 nm)

Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$
34.9	0.487	95.2	2.09	289	0.979
36.7	0.595	103	2.10	336	0.829
40.2	0.771	113	2.06	388	0.700
43.8	0.951	124	1.98	451	0.580
47.9	1.13	143	1.82	521	0.481
54.7	1.38	159	1.67	570	0.431
61.3	1.60	180	1.51	605	0.398
67.3	1.74	204	1.36		
74.6	1.90	227	1.23		
88.5	2.05	262	1.08		

Cont. Next Column   Cont. Next Column



Reference: G. M. Lawrence, Phys. Rev. A 2, 397 (1970)

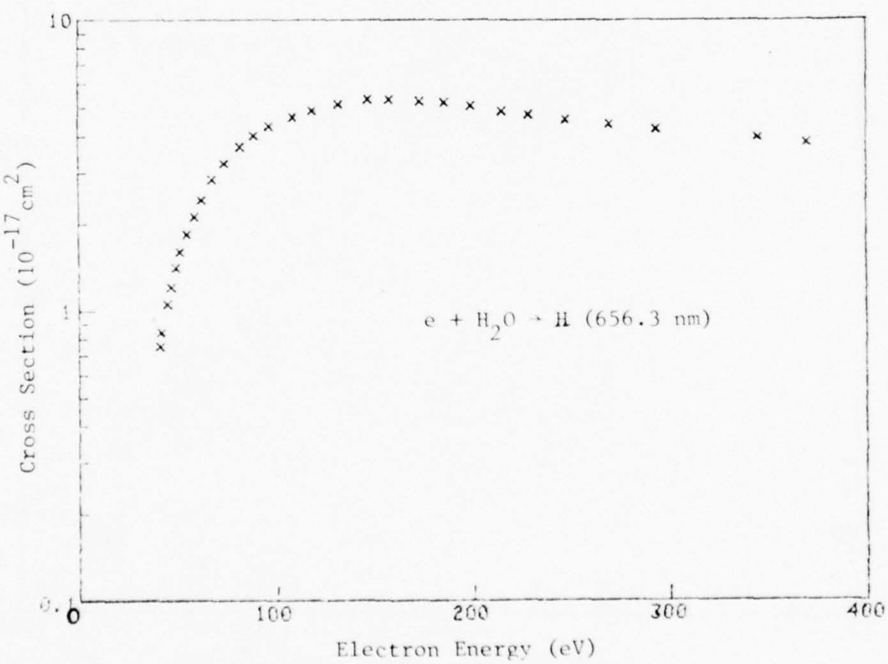
Tabular and Graphical Data C-3.10c. Cross sections for electron impact dissociation of H_2O to form excited fragments.

$e + H_2O \rightarrow H$ (656.3 nm)

Electron Energy (eV)	Cross Section ($10^{-17} cm^2$)	Electron Energy (eV)	Cross Section ($10^{-17} cm^2$)	Electron Energy (eV)	Cross Section ($10^{-17} cm^2$)
41	0.756	74	3.23	190	5.22
41	0.842	82	3.67	200	5.08
44	1.06	89	4.01	210	4.89
46	1.20	97	4.33	230	4.74
49	1.41	110	4.66	250	4.57
51	1.60	120	4.90	270	4.42
54	1.85	130	5.16	290	4.25
58	2.12	150	5.36	350	3.97
62	2.41	160	5.34	370	3.82
68	2.84	170	5.28	400	3.65

Cont. Next Column

Cont. Next Column

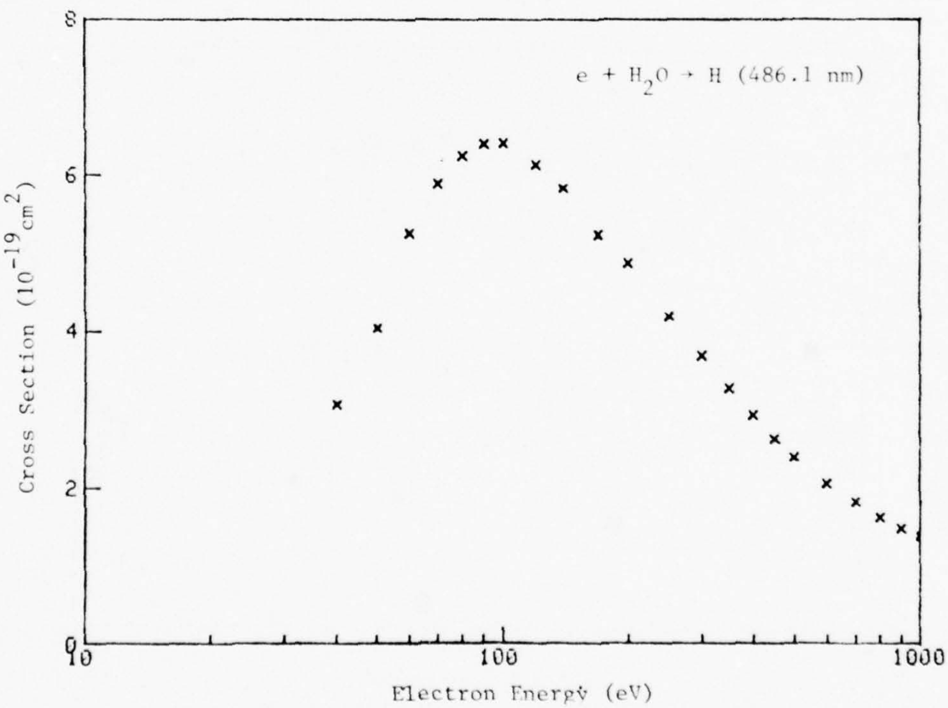


Reference: S. Tsurubuchi, T. Iwai and T. Horie, J. Phys. Soc. Japan <u>36</u>, 537 (1974)

Tabular and Graphical Data C-3.10d. Cross sections for electron impact dissociation of H_2O to form excited fragments.

$e + H_2O \rightarrow H$ (486.1 nm)

Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$
40	3.1	140	5.8	500	2.4
50	4.0	170	5.2	600	2.1
60	5.3	200	4.9	700	1.8
70	5.9	250	4.2	800	1.6
80	6.3	300	3.7	900	1.5
90	6.4	350	3.3	1000	1.4
100	6.4	400	2.9		
120	6.1	450	2.6		
Cont. Next Column		Cont. Next Column			



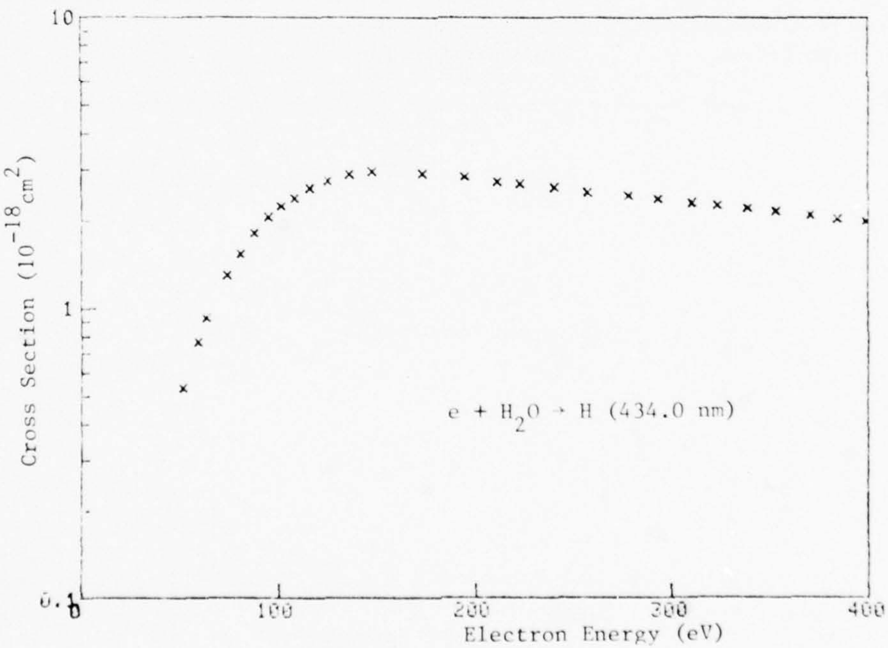
Reference: C. I. M. Beenakker, F. J. de Heer, H. B. Krop, and G. R. Mohlmann, Chem. Phys. 6, 445 (1974)

Tabular and Graphical Data C-3.10e. Cross sections for electron impact dissociation of H_2O to form excited fragments.

$e + H_2O \rightarrow H$ (434.0 nm)

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
51	0.535	120	2.76	290	2.40
59	0.766	140	2.90	310	2.32
63	0.928	150	2.96	320	2.27
73	1.30	170	2.93	340	2.22
80	1.54	190	2.85	350	2.16
87	1.82	210	2.74	370	2.10
95	2.06	220	2.69	380	2.04
100	2.25	240	2.61	400	2.00
110	2.40	260	2.53		
120	2.59	280	2.45		

Cont. Next Column   Cont. Next Column

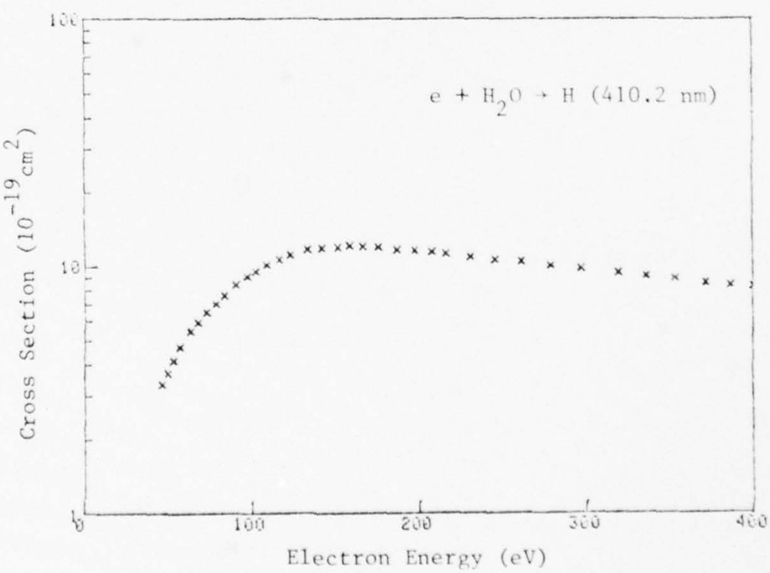


Reference: S. Tsurubuchi, T. Iwai and T. Horie, J. Phys. Soc. Japan 36, 537 (1974)

Tabular and Graphical Data C-3.10f. Cross sections for electron impact dissociation of H_2O to form excited fragments.

$e + H_2O \rightarrow H$ (410.2 nm)

Electron Energy eV	Cross Section $10^{-19}cm^2$	Electron Energy eV	Cross Section $10^{-19}cm^2$	Electron Energy eV	Cross Section $10^{-19}cm^2$
46	3.32	120	10.7	250	10.7
50	3.70	120	11.1	260	10.5
53	4.16	130	11.7	280	10.1
57	4.70	140	11.9	300	9.81
63	5.46	150	12.0	320	9.42
68	5.90	160	12.1	340	9.10
73	6.49	170	12.1	350	8.90
78	7.03	180	12.0	370	8.56
83	7.60	190	11.8	390	8.36
90	8.43	200	11.7	400	8.22
97	9.08	210	11.5		
100	9.57	220	11.3		
110	10.1	230	11.0		
Cont. Next Column		Cont. Next Column			



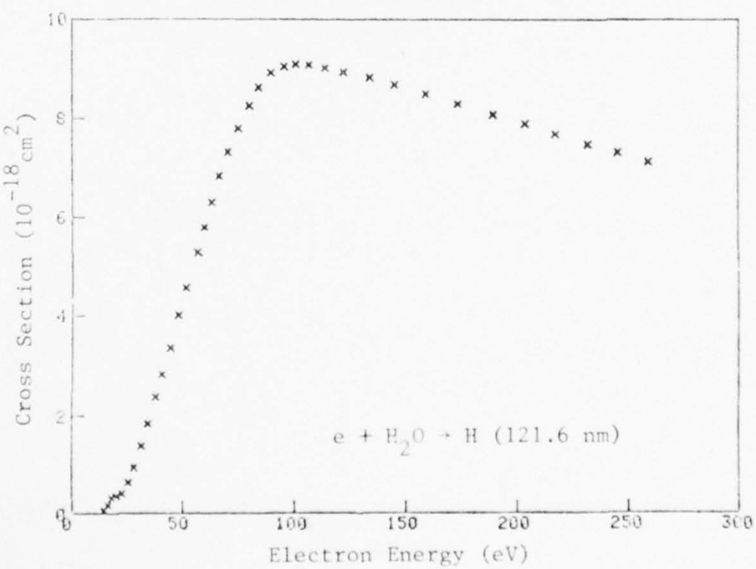
Reference: S. Tsurubuchi, T. Iwai and T. Horie, J. Phys. Soc. Japan 36, 537 (1974)

Tabular and Graphical Data C-3.10g. Cross sections for electron impact dissociation of H_2O to form excited fragments.

$e + H_2O \rightarrow H$ (121.6 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
14.6	0.0498	51.4	4.55	114	9.03
16.0	0.156	56.7	5.28	122	8.95
17.8	0.308	59.6	5.78	134	8.83
20.0	0.340	62.7	6.28	145	8.69
22.8	0.397	66.2	6.82	159	8.49
25.4	0.632	70.0	7.31	174	8.29
28.1	0.934	74.7	7.79	189	8.08
31.4	1.37	79.7	8.26	204	7.89
34.4	1.83	83.9	8.62	218	7.69
37.7	2.37	89.3	8.92	232	7.48
40.7	2.82	95.4	9.06	246	7.31
44.2	3.35	101	9.11	259	7.13
47.9	4.00	107	9.09		

Cont. Next Column   Cont. Next Column



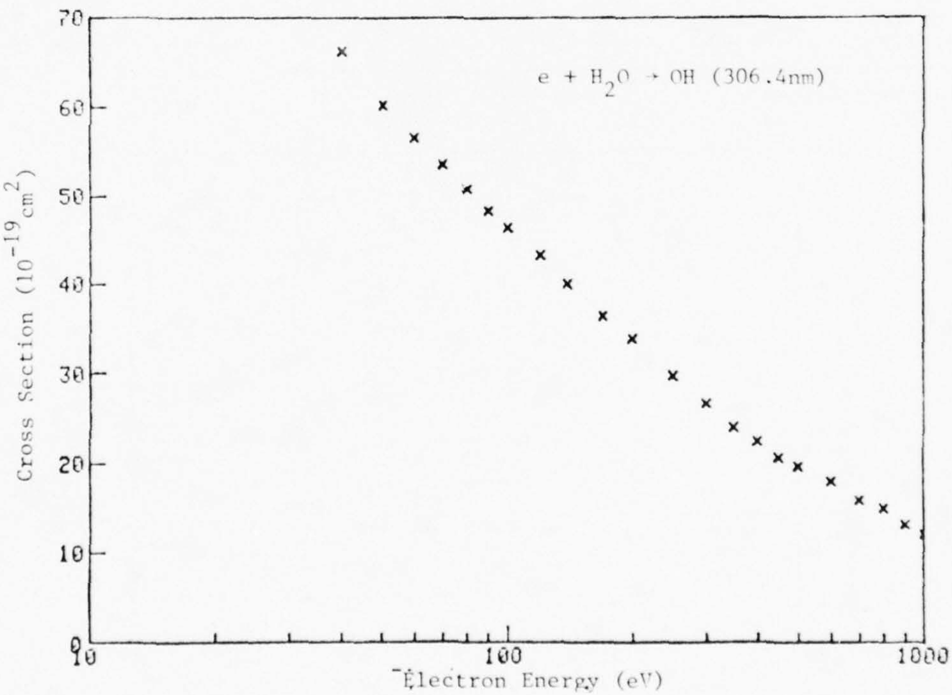
Reference: H. D. Morgan and J. E. Mentall, J. Chem. Phys. 60, 4734 (1974)

Tabular and Graphical Data C-3.10h. Cross sections for electron impact dissociation of H_2O to form excited fragments.

$e + H_2O \rightarrow OH$ (306.4 nm)

Electron Energy eV	Cross Section $10^{-19}cm^2$	Electron Energy eV	Cross Section $10^{-19}cm^2$	Electron Energy eV	Cross Section $10^{-19}cm^2$
40	66.3	140	40.0	500	19.6
50	60.3	170	36.4	600	17.9
60	56.6	200	33.9	700	15.8
70	53.5	250	29.7	800	14.9
80	50.8	300	26.6	900	13.1
90	48.3	350	24.0	1000	12.1
100	46.4	400	22.4		
120	43.2	450	20.6		

Cont. Next Column   Cont. Next Column



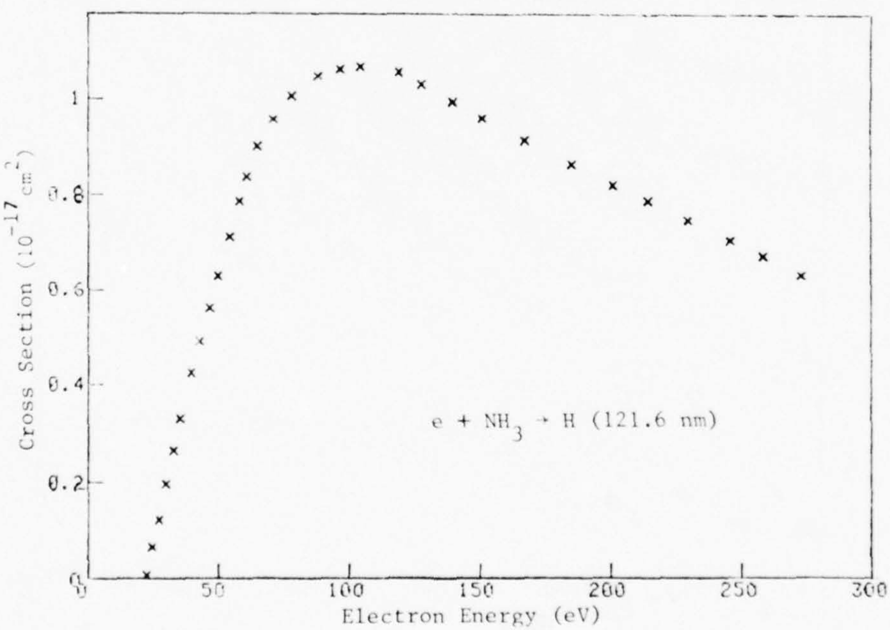
Reference: C. I. M. Beenakker, F. J. de Heer, H. B. Krop and G. R. Mohlmann, Chem. Phys. 6, 445 (1974)

Tabular and Graphical Data C-3.11a. Cross sections for electron impact dissociation of NH_3 to form excited fragments.

$e + NH_3 \rightarrow H$ (121.6 nm)

Electron Energy eV	Cross Section $10^{-17} cm^2$	Electron Energy eV	Cross Section $10^{-17} cm^2$	Electron Energy eV	Cross Section $10^{-17} cm^2$
22.3	0.00565	57.9	0.786	151	0.963
24.5	0.0648	60.8	0.839	168	0.916
27.2	0.121	65.0	0.902	185	0.866
29.8	0.197	71.0	0.959	201	0.822
32.6	0.265	78.0	1.01	215	0.790
35.2	0.331	87.9	1.05	230	0.748
39.3	0.422	96.3	1.06	246	0.705
42.8	0.490	104	1.07	259	0.672
46.5	0.560	119	1.06	273	0.631
49.7	0.630	128	1.03		
54.3	0.712	140	0.997		

Cont. Next Column   Cont. Next Column



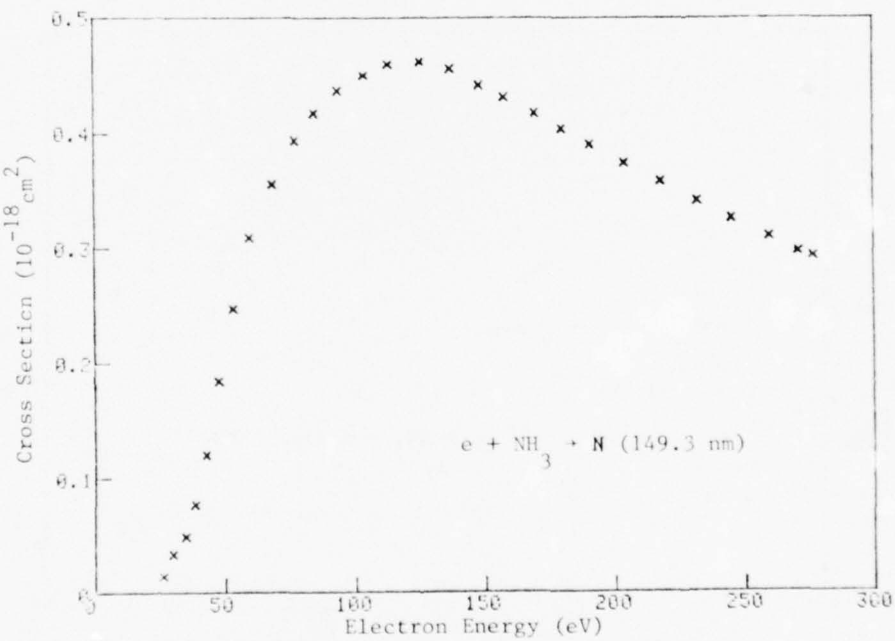
Reference: H. D. Morgan and J. E. Mentall, J. Chem. Phys. 60, 4734 (1974)

Tabular and Graphical Data C-3.11b. Cross sections for electron impact dissociation of NH_3 to form excited fragments.

$e + NH_3 \rightarrow N$ (149.3 nm)

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
25.7	0.0139	84.5	0.418	191	0.391
29.7	0.0332	93.6	0.437	204	0.374
34.5	0.0479	104	0.450	218	0.359
38.1	0.0758	113	0.460	232	0.342
42.5	0.120	126	0.462	245	0.326
47.6	0.183	137	0.456	260	0.311
53.3	0.247	148	0.442	271	0.297
59.3	0.308	158	0.431	277	0.293
68.5	0.356	170	0.418		
77.0	0.394	180	0.404		

Cont. Next Column   Cont. Next Column



Reference: H. D. Morgan and J. E. Mentall, J. Chem. Phys. 60, 4734 (1974)

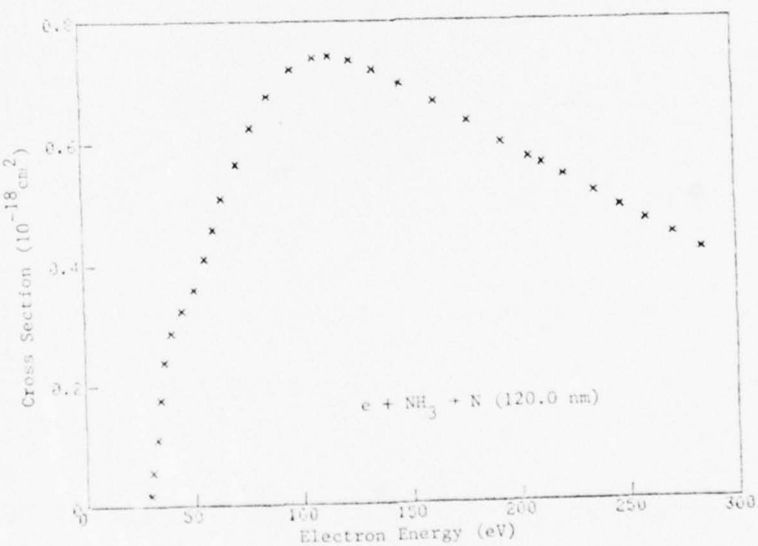
Tabular and Graphical Data C-3.11c. Cross sections for electron impact dissociation of NH_3 to form excited fragments.

$e + NH_3 \rightarrow N$ (120.0 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
29.2	0.0174	71.0	0.566	193	0.599
30.1	0.0546	77.7	0.626	206	0.574
32.3	0.110	85.7	0.678	212	0.563
34.4	0.175	97.2	0.721	222	0.543
36.1	0.239	107	0.740	236	0.516
39.5	0.286	115	0.743	248	0.491
44.6	0.323	124	0.737	259	0.467
50.4	0.358	135	0.721	271	0.443
55.3	0.410	147	0.697	284	0.417
59.6	0.458	162	0.667		
64.0	0.510	178	0.634		

Cont. Next Column

Cont. Next Column



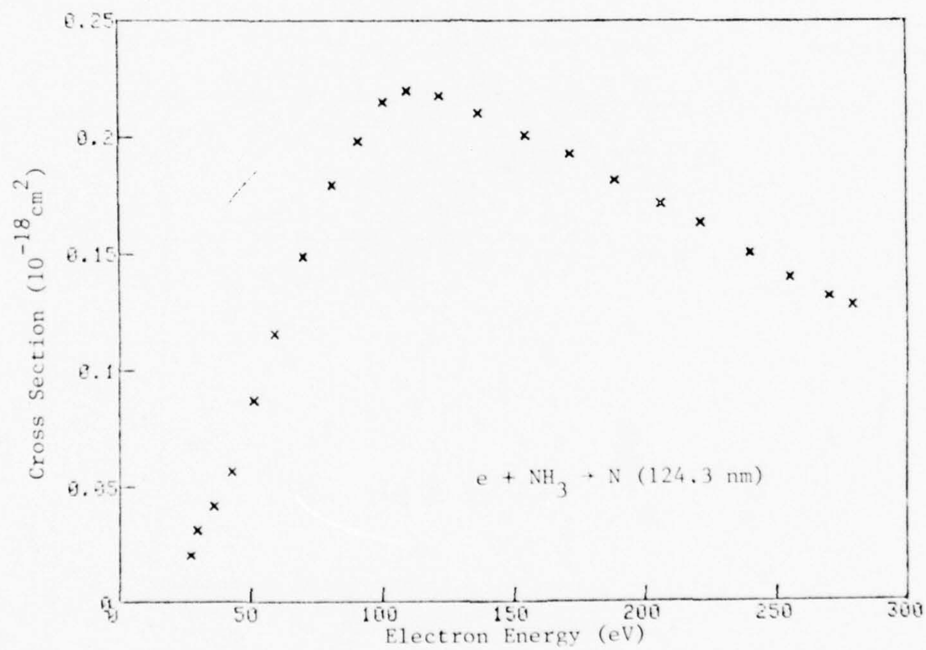
Reference: H. D. Morgan and J. E. Mentall, J. Chem. Phys. 60, 4734 (1974)

Tabular and Graphical Data C-3.11d. Cross sections for electron impact dissociation of NH_3 to form excited fragments.

$e + NH_3 \rightarrow N$ (124.3 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
26.9	0.0203	91.1	0.198	207	0.172
29.4	0.0311	100	0.215	221	0.164
35.5	0.0416	110	0.220	240	0.151
42.8	0.0565	122	0.218	255	0.140
51.1	0.0870	137	0.210	270	0.132
58.9	0.116	155	0.201	279	0.128
70.1	0.149	172	0.193		
81.2	0.180	189	0.182		

Cont. Next Column   Cont. Next Column



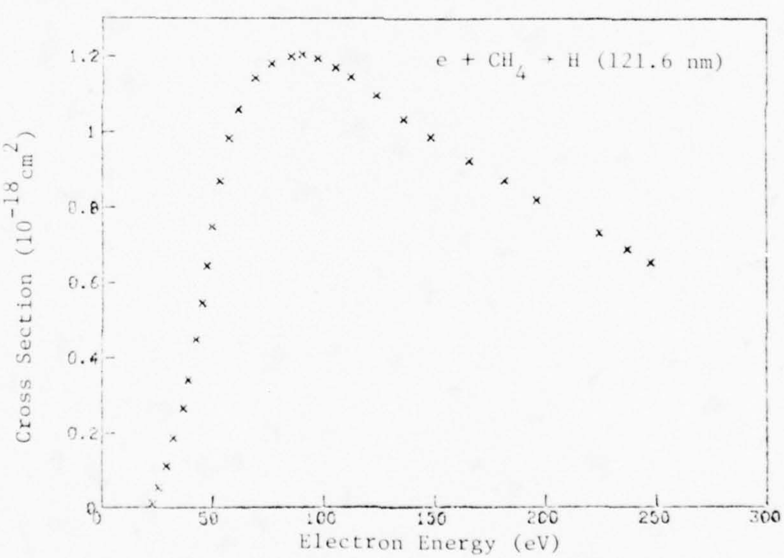
Reference: H. D. Morgan and J. E. Mentall, J. Chem. Phys. 60, 4734 (1974)

Tabular and Graphical Data C-3.12a. Cross sections for electron impact dissociation of CH_4 to form excited fragments.

$e + CH_4 \rightarrow H$ (121.6 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
22.6	0.00976	53.0	0.871	123	1.10
25.4	0.0547	57.1	0.984	136	1.04
29.0	0.112	61.7	1.06	148	0.988
32.2	0.187	68.7	1.14	166	0.925
36.6	0.266	76.2	1.18	181	0.873
38.9	0.342	84.9	1.20	196	0.823
42.5	0.449	89.9	1.21	224	0.733
45.2	0.545	96.8	1.20	237	0.691
47.0	0.646	105	1.17	247	0.655
49.4	0.750	112	1.15		

Cont. Next Column   Cont. Next Column



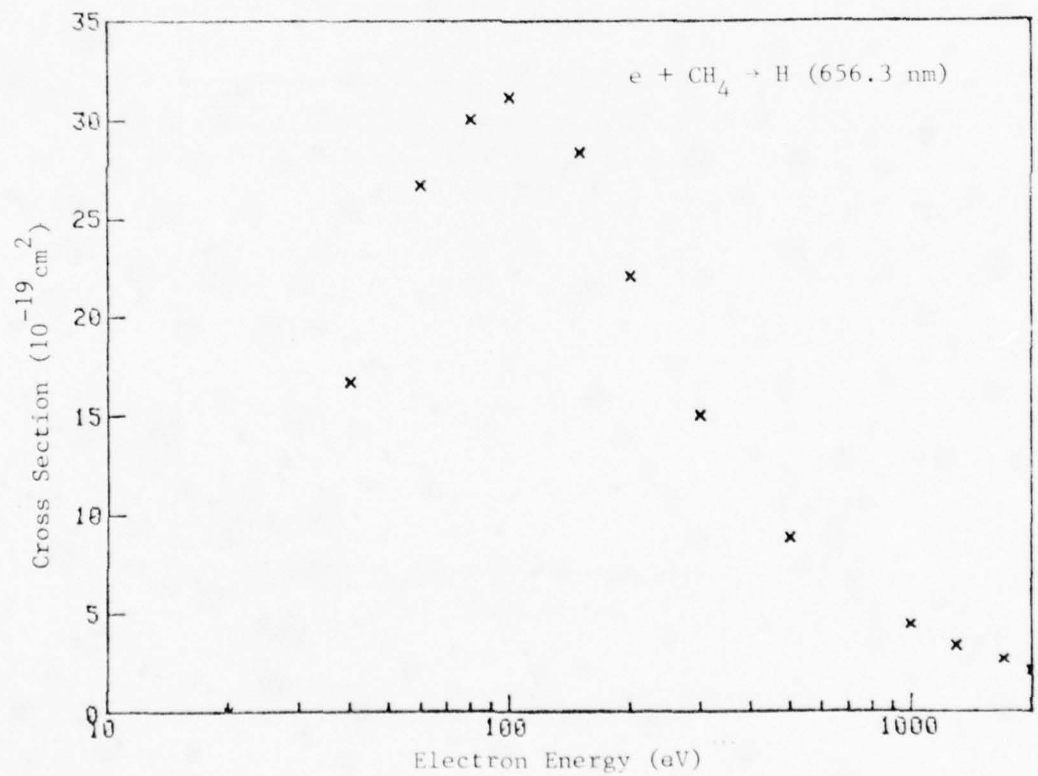
Reference: H. D. Morgan and J. E. Mentall, J. Chem. Phys. 60, 4734 (1974)

Tabular and Graphical Data C-3.12b. Cross sections for electron impact dissociation of CH_4 to form excited fragments.

$e + CH_4 \rightarrow H$ (656.3 nm)

Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$
20	0	300	15.0
40	16.7	500	8.80
60	26.7	1000	4.40
80	30.1	1300	3.30
100	31.2	1700	2.60
150	28.4	2000	2.10
200	22.1		

Cont. Next Column



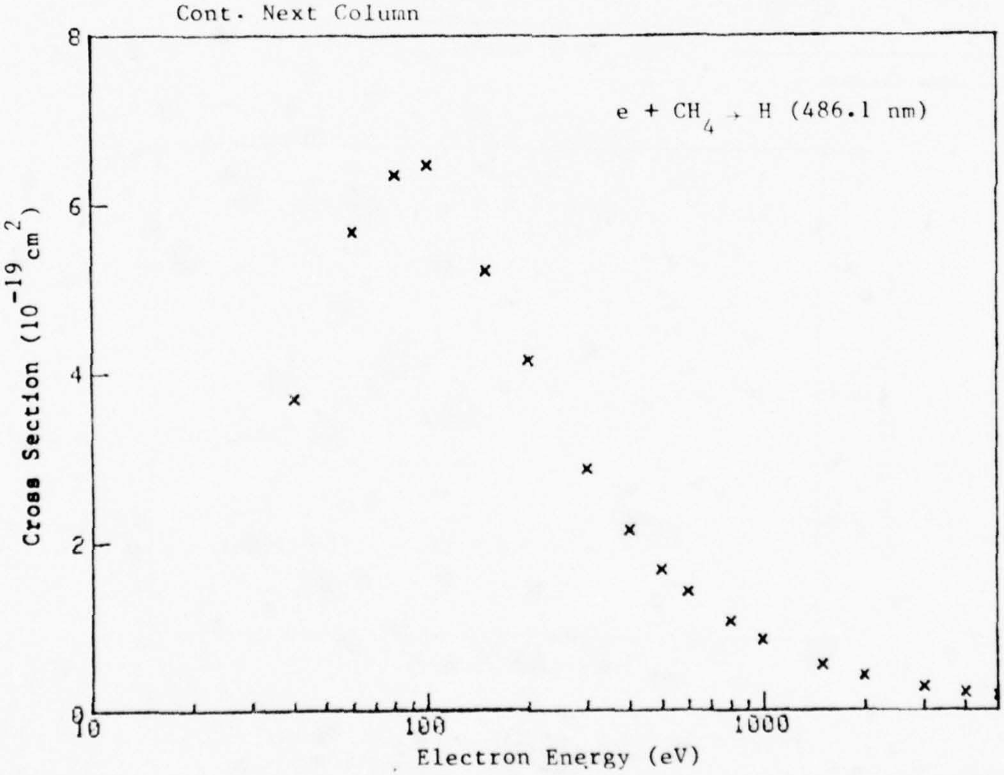
Reference: G. R. Mohlmann and F. J. de Heer, Chem. Phys. 19, 233 (1977)

Tabular and Graphical Data C-3.12c. Cross sections for electron impact dissociation of CH_4 to form excited fragments.

$$e + CH_4 \rightarrow H\ (486.1\ \text{nm})$$

Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$
40	3.69	600	1.39
60	5.68	800	1.04
80	6.36	1000	0.820
100	6.48	1500	0.524
150	5.21	2000	0.396
200	4.15	3000	0.267
300	2.86	4000	0.204
400	2.12	5000	0.167
500	1.65		

Cont. Next Column



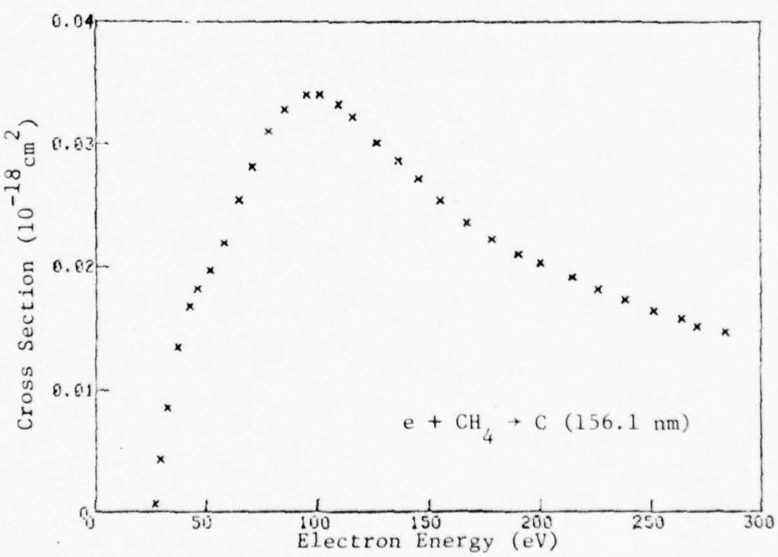
Reference: J. F. M. Aarts, C. J. M. Beenakker, and F. J. de Heer, Physica 53, 32 (1971)

Tabular and Graphical Data C-3.12d. Cross sections for electron impact dissociation of CH_4 to form excited fragments.

$e + CH_4 \rightarrow C$ (156.1 nm)

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
27.1	0.000625	85.2	0.0328	191	0.0210
		94.9	0.0340	201	0.0203
29.0	0.00426	101	0.0341	215	0.0191
32.3	0.00854	109	0.0333	226	0.0181
36.9	0.0135	116	0.0322	239	0.0173
42.2	0.0167	127	0.0302	251	0.0164
45.7	0.0181	137	0.0287	264	0.0157
51.3	0.0197	145	0.0272	271	0.0151
57.7	0.0219	156	0.0254	284	0.0147
64.7	0.0254	168	0.0236		
70.3	0.0281	179	0.0223		
78.0	0.0311				

Cont. Next Column (columns 1 and 2)



Reference: H. D. Morgan and J. E. Mentall, J. Chem. Phys. 60, 4734 (1974)

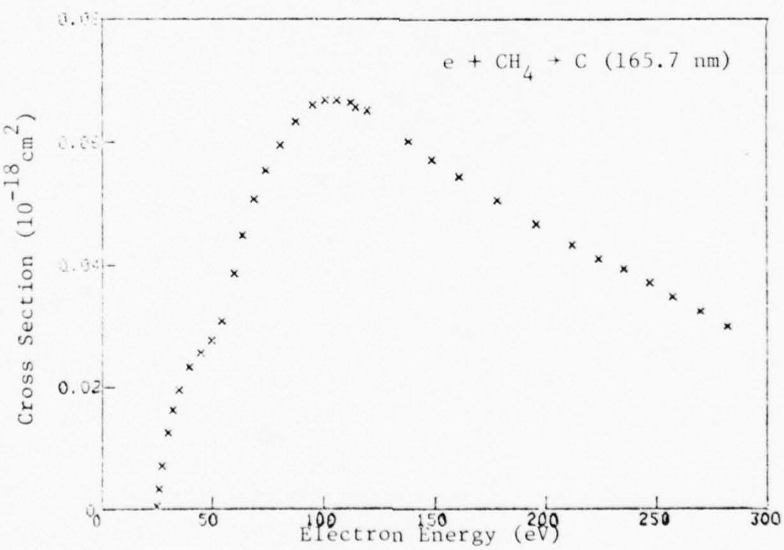
Tabular and Graphical Data C-3.12e. Cross sections for electron impact dissociation of CH_4 to form excited fragments.

$e + CH_4 \rightarrow C$ (165.7 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
24.7	0.000487	68.5	0.0507	161	0.0544
		73.6	0.0554	178	0.0506
25.4	0.00336	80.3	0.0595	196	0.0466
26.8	0.00719	87.3	0.0634	212	0.0432
29.7	0.0126	95.0	0.0660	224	0.0409
31.9	0.0163	101	0.0668	235	0.0393
34.8	0.0195	106	0.0669	247	0.0369
39.1	0.0232	112	0.0664	257	0.0347
44.3	0.0255	114	0.0657	270	0.0323
49.2	0.0275	120	0.0651	282	0.0298
53.9	0.0307	138	0.0602		
59.4	0.0385	149	0.0572		
63.3	0.0448				

Cont. Next Column

Cont. Next Column



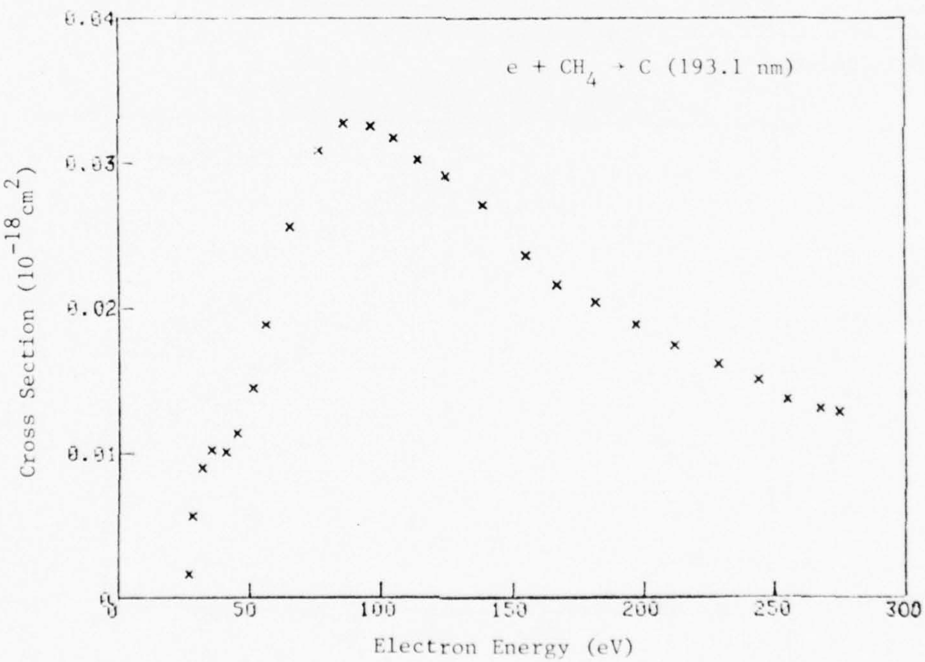
Reference: H. D. Morgan and J. E. Mentall, J. Chem. Phys. 60, 4734 (1974)

Tabular and Graphical Data C-3.12f. Cross sections for electron impact dissociation of CH_4 to form excited fragments.

$e + CH_4 \rightarrow C$ (193.1 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
26.7	0.00163	76.4	0.0309	182	0.0203
28.0	0.00565	85.9	0.0327	197	0.0188
31.4	0.00897	96.3	0.0326	212	0.0173
35.1	0.0102	105	0.0317	229	0.0161
40.7	0.0101	114	0.0303	244	0.0150
44.9	0.0113	125	0.0291	255	0.0136
50.9	0.0144	139	0.0271	268	0.0130
55.8	0.0188	155	0.0236	275	0.0128
65.3	0.0256	167	0.0216		

Cont. Next Column Cont. Next Column



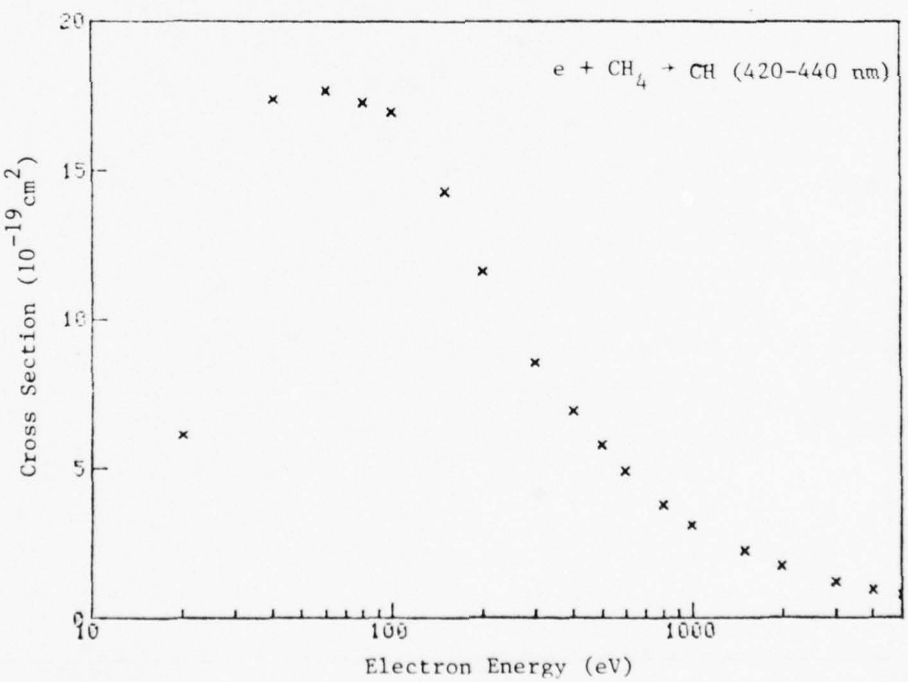
Reference: H. D. Morgan and J. E. Mentall, J. Chem. Phys. 60, 4734 (1974)

Tabular and Graphical Data C-3.12g. Cross sections for electron impact dissociation of CH_4 to form excited fragments.

$e + CH_4 \rightarrow CH$ (420.0-440.0 nm)

Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$
20	6.10	600	4.90
40	17.4	800	3.77
60	17.7	1000	3.09
80	17.3	1500	2.23
100	17.0	2000	1.73
150	14.3	3000	1.20
200	11.6	4000	0.925
300	8.53	5000	0.785
400	6.91		
500	5.75		

Cont. Next Column



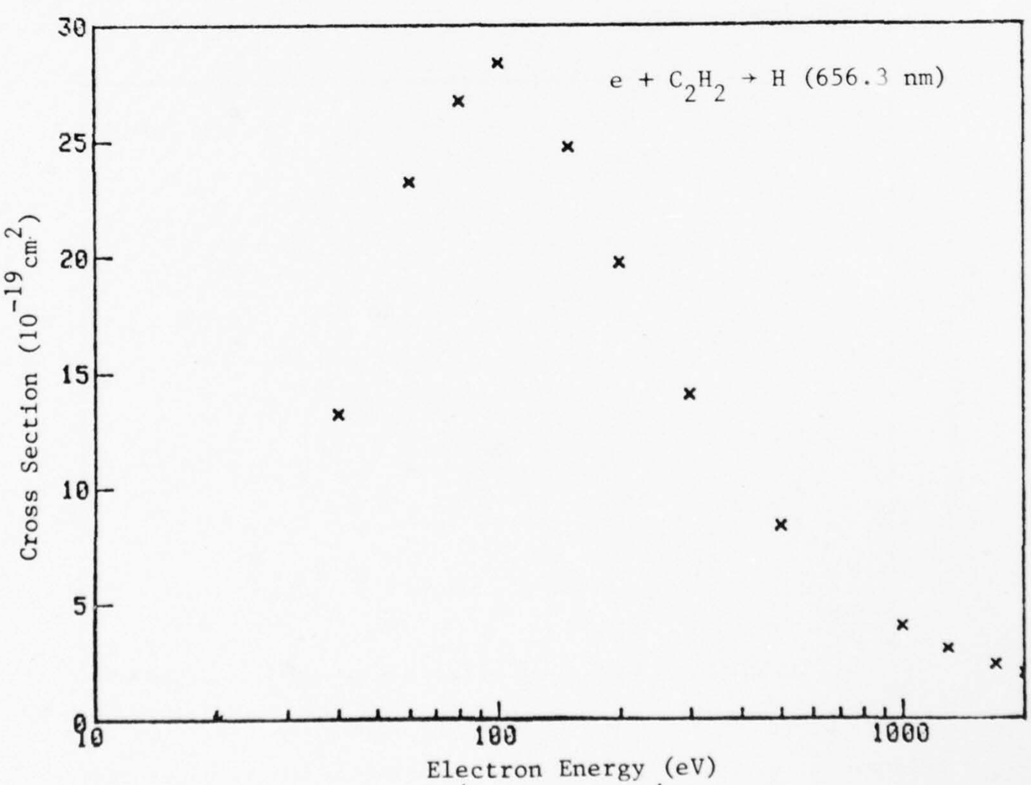
Reference: J. F. M. Aarts, C. I. M. Beenaker, and F. J. de Heer, Physica 53, 32 (1971)

Tabular and Graphical Data C-3.13a. Cross sections for electron impact dissociation of C_2H_2 to form excited fragments.

$e + C_2H_2 \rightarrow H$ (656.3 nm)

Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$
20	0	300	14.0
40	13.2	500	8.30
60	23.3	1000	4.00
80	26.8	1300	3.00
100	28.4	1700	2.30
150	24.8	2000	1.90
200	19.8		

Cont. Next Column



Reference: G. R. Mohlmann and F. J. de Heer, Chem. Phys. 19, 233 (1977)

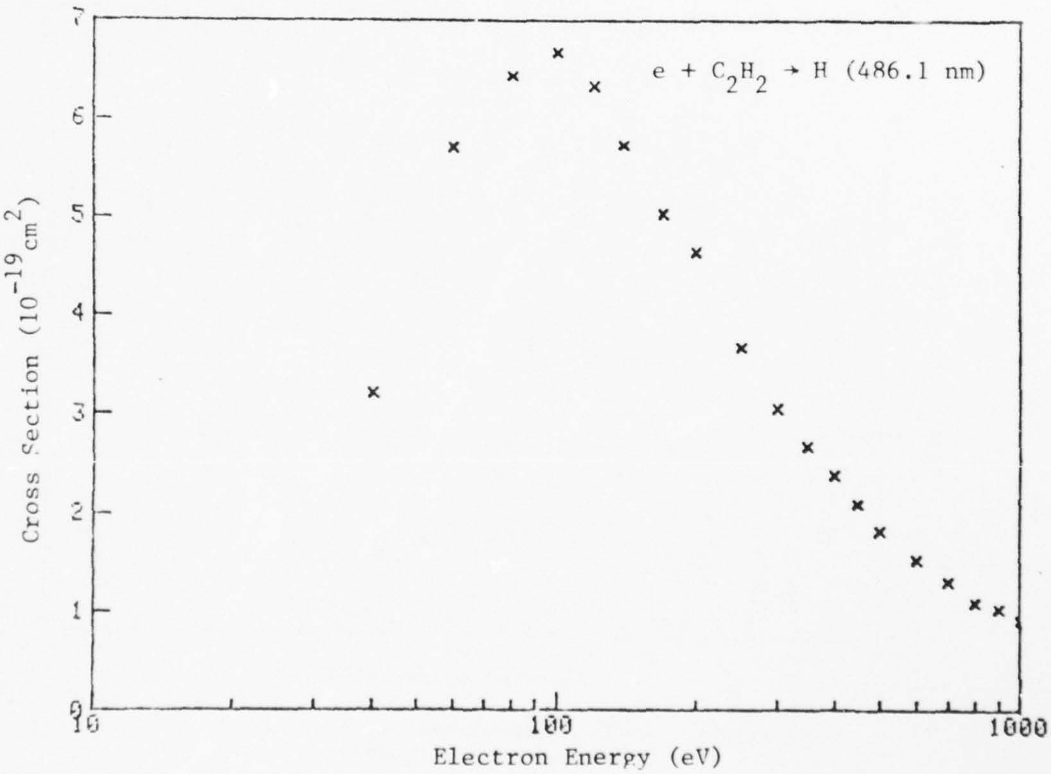
Tabular and Graphical Data C-3.13b. Cross sections for electron impact dissociation of C_2H_2 to form excited fragments.

$e + C_2H_2 \rightarrow H$ (486.1 nm)

Electron Energy eV	Cross Section $10^{-19}cm^2$	Electron Energy eV	Cross Section $10^{-19}cm^2$	Electron Energy eV	Cross Section $10^{-19}cm^2$
40	3.20	200	4.64	600	1.52
60	5.71	250	3.67	700	1.30
80	6.45	300	3.05	800	1.09
100	6.68	350	2.67	900	1.02
120	6.34	400	2.38	1000	0.908
140	5.74	450	2.09		
170	5.03	500	1.81		

Cont. Next Column

Cont. Next Column



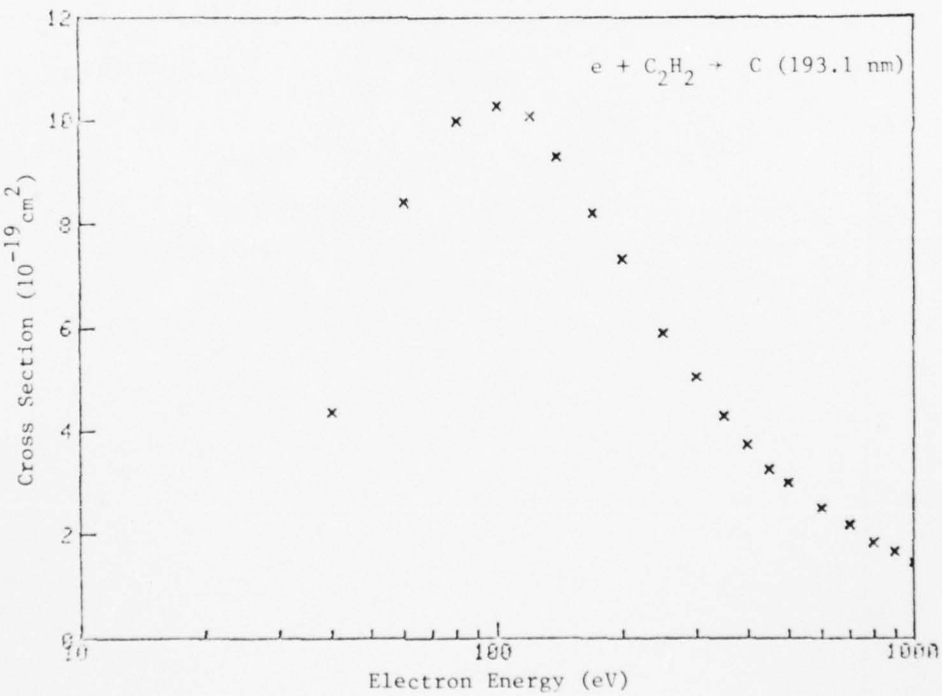
Reference: C. I. M. Beenakker and F. J. de Heer, Chem. Phys. 6, 291 (1974)

Tabular and Graphical Data C-3.13c. Cross sections for electron impact dissociation of C_2H_2 to form excited fragments.

$e + C_2H_2 \rightarrow C$ (193.1 nm)

Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$
40	4.35	200	7.34	600	2.50
60	8.43	250	5.90	700	2.17
80	10.00	300	5.04	800	1.83
100	10.3	350	4.28	900	1.66
120	10.1	400	3.73	1000	1.44
140	9.31	450	3.25		
170	8.23	500	2.99		

Cont. Next Column Cont. Next Column



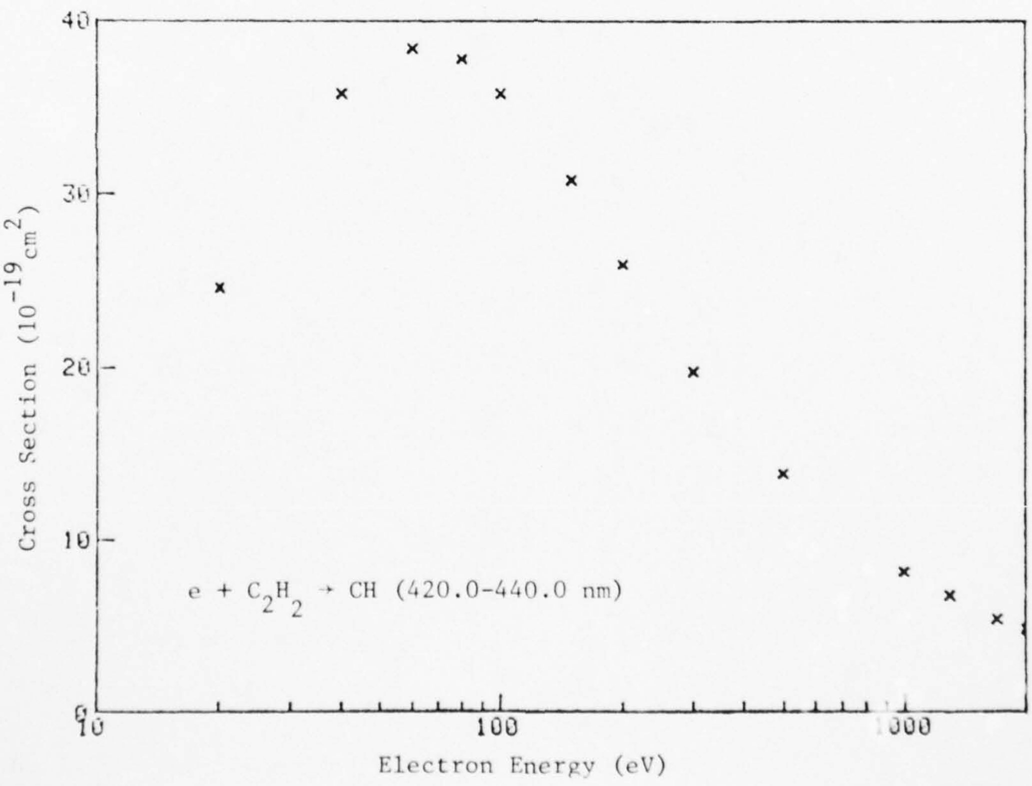
Reference: C. I. M. Beenakker and F. J. de Heer, Chem. Phys. 6, 291 (1974)

Tabular and Graphical Data C-3.13d. Cross sections for electron impact dissociation of C_2H_2 to form excited fragments.

$$e + C_2H_2 \rightarrow CH\ (420.0\text{-}440.0\ \text{nm})$$

Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$
20	24.6	300	19.7
40	35.8	500	13.8
60	38.4	1000	8.10
80	37.8	1300	6.70
100	35.8	1700	5.40
150	30.8	2000	4.80
200	25.9		

Cont. Next Column



Reference: G. R. Mohlmann and F. J. de Heer, Chem. Phys. 19, 233 (1977)

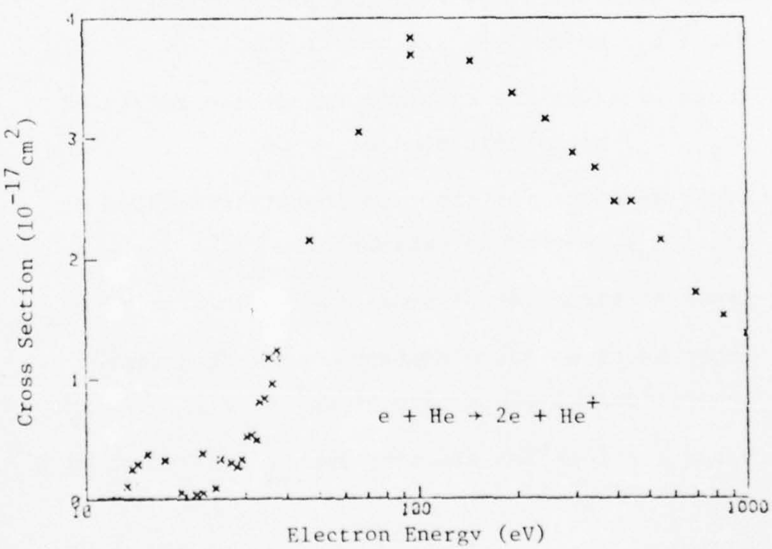
C-4. IONIZATION BY ELECTRON IMPACT

CONTENTS

Tabular and Graphical Data C-4.1. Cross sections for electron impact ionization of He.

$$e + He \rightarrow 2e + He^{+}$$

Electron Energy eV	Cross Section $10^{-17} cm^2$	Electron Energy eV	Cross Section $10^{-17} cm^2$	Electron Energy eV	Cross Section $10^{-17} cm^2$
12.3	0	28.3	0.270	97.0	3.84
13.3	0.110	29.3	0.330	97.0	3.70
13.8	0.250	30.3	0.520	147	3.65
14.3	0.290	31.3	0.530	197	3.38
15.3	0.370	32.3	0.490	247	3.16
17.3	0.320	33.3	0.810	297	2.88
19.3	0.0600	34.3	0.840	347	2.75
21.3	0.0400	35.3	1.18	397	2.47
22.3	0.380	36.3	0.960	447	2.47
22.3	0.0500	37.3	1.24	547	2.15
24.3	0.0900	37.3	1.18	697	1.71
25.3	0.330	47.0	2.16	847	1.52
27.3	0.300	67.0	3.05	997	1.37
Cont. Next Column		Cont. Next Column			



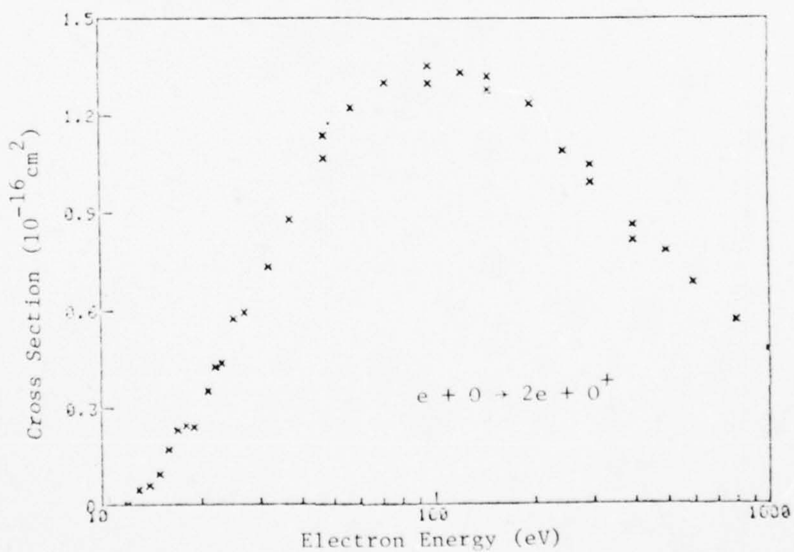
Reference: E. Brook, M. F. A. Harrison, and A. C. H. Smith, J. Phys. B. 11, 3115 (1978)

Tabular and Graphical Data C-4.2. Cross sections for electron impact ionization of O.

$$e + O \rightarrow 2e + O^+$$

Electron Energy (eV)	Cross Section ($10^{-16}cm^2$)	Electron Energy (eV)	Cross Section ($10^{-16}cm^2$)	Electron Energy (eV)	Cross Section ($10^{-16}cm^2$)
11.9	0	26.9	0.596	197	1.24
12.9	0.0470	31.9	0.735	247	1.09
13.9	0.0570	36.9	0.879	297	0.994
14.9	0.0930	47.0	1.07	297	1.05
15.9	0.170	47.0	1.14	397	0.863
16.9	0.231	57.0	1.22	397	0.816
17.9	0.246	72.0	1.30	497	0.784
18.9	0.241	97.0	1.36	597	0.686
20.9	0.353	97.0	1.30	797	0.571
21.9	0.427	122	1.33	997	0.482
22.9	0.439	147	1.28		
24.9	0.576	147	1.32		

Cont. Next Column   Cont. Next Column



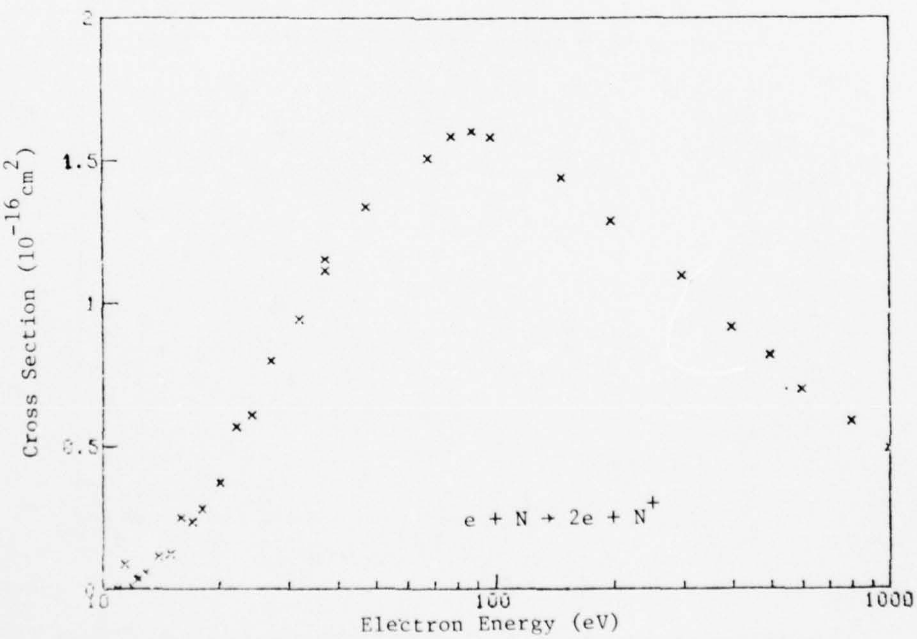
Reference: E. Brook, M. F. A. Harrison, and A. C. H. Smith, J. Phys. B. 11, 3115 (1978)

Tabular and Graphical Data C-4.3. Cross sections for electron impact ionization of N.

$$e + N \rightarrow 2e + N^+$$

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
10.9	0	19.9	0.372	87.0	1.61
11.4	0.0870	21.9	0.568	97.0	1.59
11.9	0.00700	23.9	0.608	147	1.45
12.4	0.0350	26.9	0.799	197	1.29
12.9	0.0540	31.9	0.945	297	1.10
13.9	0.113	36.9	1.16	397	0.914
14.9	0.122	37.0	1.12	497	0.816
15.9	0.248	47.0	1.34	597	0.697
16.9	0.232	67.0	1.51	797	0.587
17.9	0.280	77.0	1.59	997	0.490

Cont. Next Column   Cont. Next Column



Reference: E. Brook, M. F. A. Harrison, and A. C. H. Smith, J. Phys. B. 11, 3115 (1978)

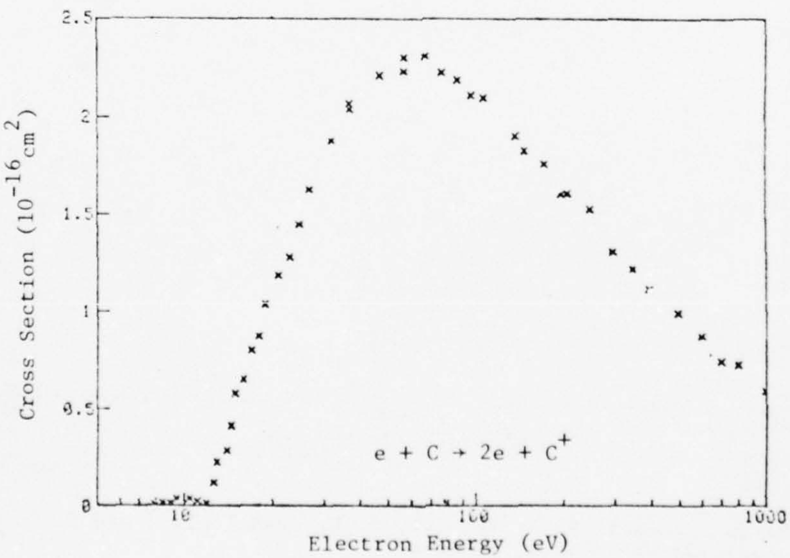
Tabular and Graphical Data C-4.4. Cross sections for electron impact ionization of C.

$$e + C \rightarrow 2e + C^+$$

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
7.90	0	18.9	1.037	107	2.103
8.40	0.01100	20.9	1.184	137	1.909
8.90	0.009000	22.9	1.282	147	1.834
		24.9	1.451	172	1.765
9.40	0.03200	26.9	1.630	197	1.608
10.4	0.03200	31.9	1.882	207	1.614
11.1	0.01900	36.9	2.073	247	1.531
11.9	0.01000	37.0	2.042	297	1.310
12.6	0.1160	47.0	2.215	347	1.220
12.9	0.2250	57.0	2.309	397	1.117
13.9	0.2830	57.0	2.239	497	0.9940
14.4	0.4120	67.0	2.315	597	0.8740
14.9	0.5810	77.0	2.234	697	0.7440
15.9	0.6530	87.0	2.193	797	0.7270
16.9	0.8000	97.0	2.118	997	0.5960
17.9	0.8720				

Cont. Next Column

Cont. Next Column



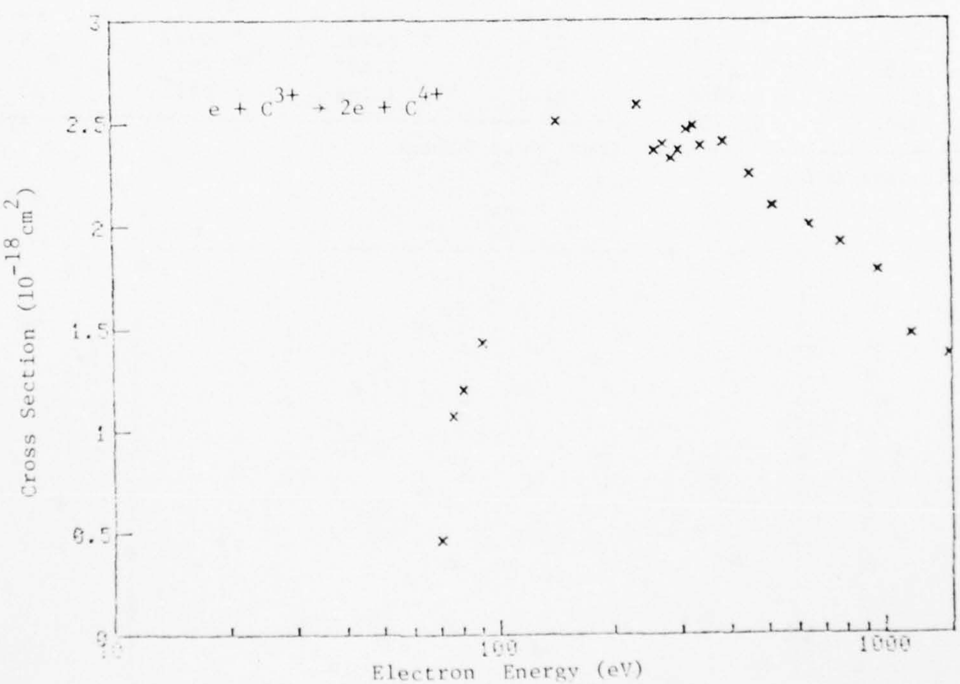
Reference: E. Brook, M. F. A. Harrison, and A. C. H. Smith, J. Phys. B 11, 3115 (1978)

Tabular and Graphical Data C-4.5. Cross sections for electron impact ionization of C^{3+}.

$$e + C^{3+} \rightarrow 2e + C^{4+}$$

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
70.3	0.460	271	2.40	451	2.25
75.4	1.07	284	2.33	516	2.10
80.6	1.20	296	2.37	645	2.00
90.2	1.43	309	2.47	773	1.92
142	2.51	322	2.49	967	1.78
232	2.59	338	2.39	1180	1.47
258	2.37	387	2.41	1480	1.37

Cont. Next Column Cont. Next Column

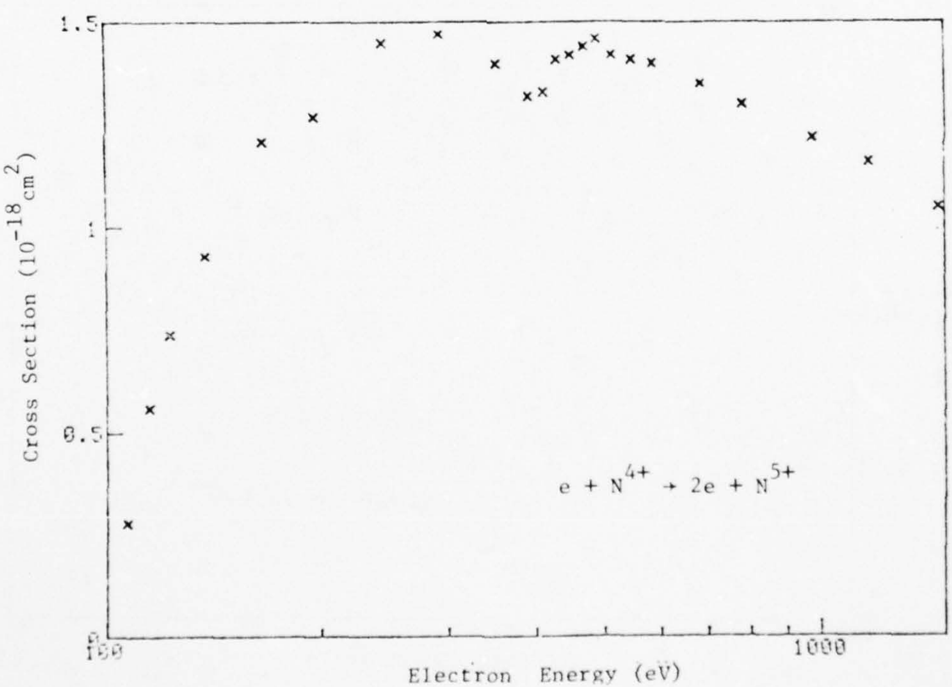


Reference: D. H. Crandall, R. A. Phaneuf, B. E. Hasselquist, and D. C. Gregory, submitted to J. Phys. B, 1979

Tabular and Graphical Data C-4.6. Cross sections for electron impact ionization of N^{4+}.

$$e + N^{4+} \rightarrow 2e + N^{5+}$$

Electron Energy eV	Cross Section 10^{-18} cm^2	Electron Energy eV	Cross Section 10^{-18} cm^2	Electron Energy eV	Cross Section 10^{-18} cm^2
107	0.280	352	1.40	548	1.41
115	0.560	391	1.32	587	1.40
122	0.740	411	1.33	685	1.35
137	0.930	431	1.41	783	1.30
166	1.21	450	1.42	979	1.22
196	1.27	470	1.44	1170	1.16
245	1.45	489	1.46	1470	1.05
294	1.47	514	1.42		
Cont. Next Column		Cont. Next Column			



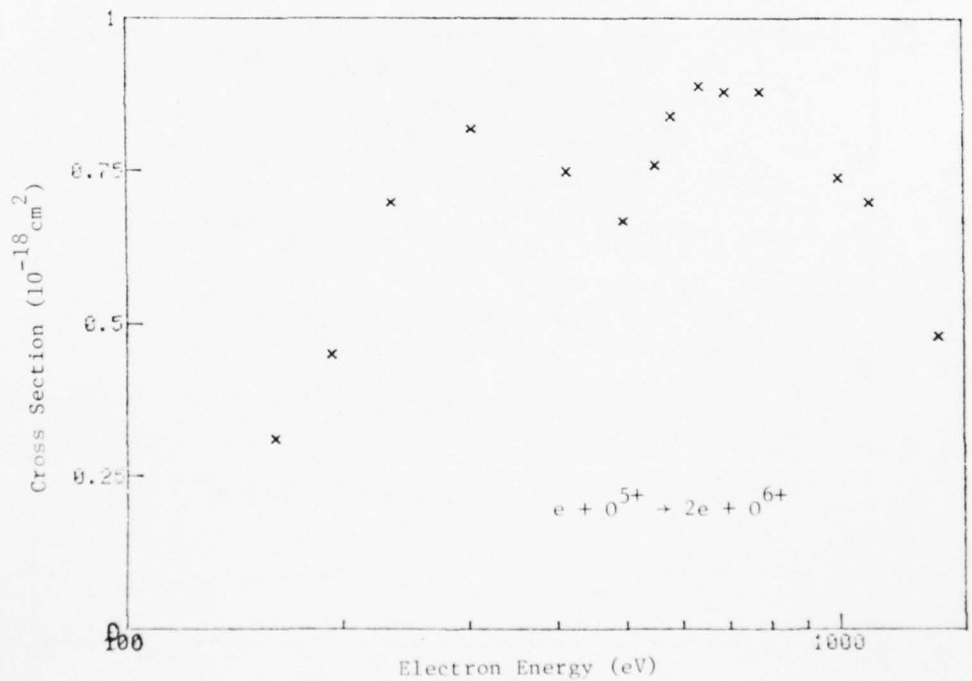
Reference: D. H. Crandall, R. A. Phaneuf, B. E. Hasselquist, and D. C. Gregory, submitted to J. Phys. B, 1979

Tabular and Graphical Data C-4.7. Cross sections for electron impact ionization of O^{5+}.

$$e + O^{5+} \rightarrow 2e + O^{6+}$$

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
162	0.31	580	0.84
193	0.45	635	0.89
235	0.70	691	0.88
304	0.82	773	0.88
414	0.75	997	0.74
497	0.67	1100	0.70
552	0.76	1380	0.48

Cont. Next Column

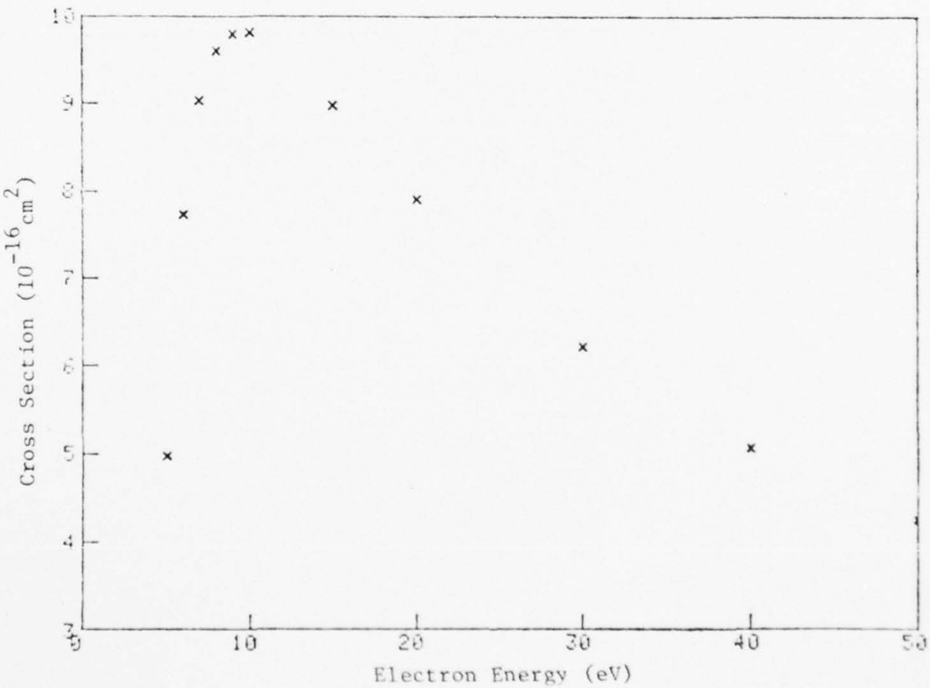


Reference: D. H. Crandall, R. A. Phaneuf, B. E. Hasselquist, and D. C. Gregory, submitted to J. Phys. B, 1979

Tabular and Graphical Data C-4.8. Cross sections for electron impact ionization of Ne_2^* $(^1\Sigma_u^+)$ metastable excimer.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
5.0	4.97	15	8.98
6.0	7.73	20	7.91
7.0	9.04	30	6.21
8.0	9.61	40	5.06
9.0	9.80	50	4.25
10.0	9.82		

Cont. Next Column

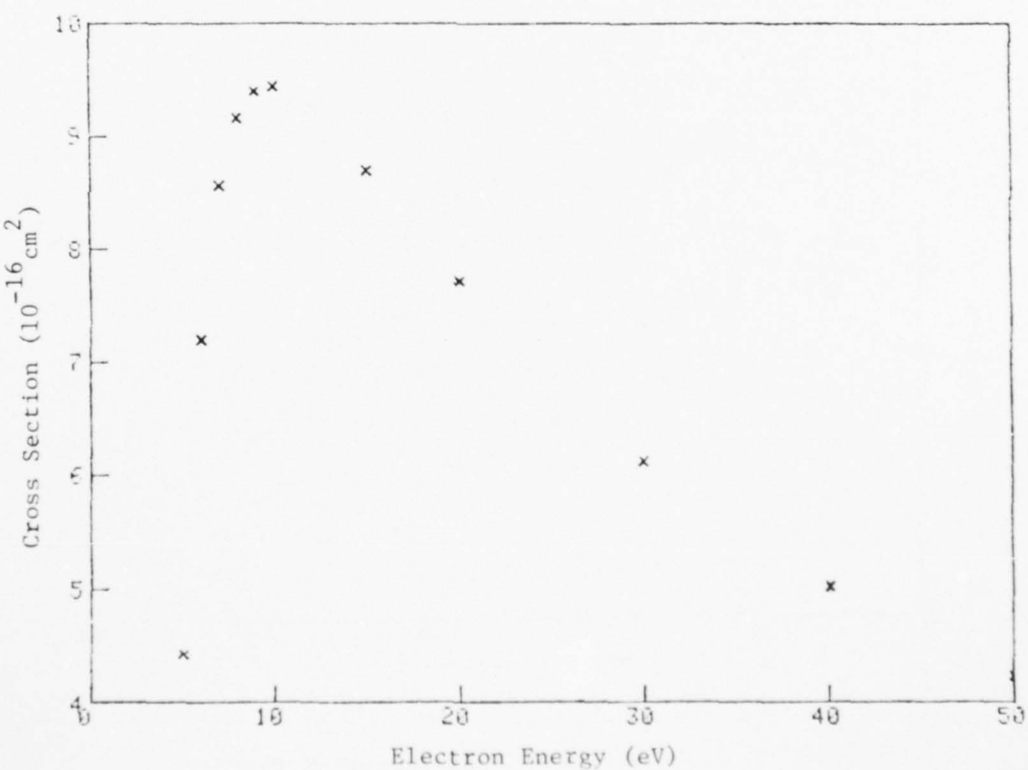


Reference: K. J. McCann, M. R. Flannery, and A. Hazi, submitted to Applied Phys. Lett., 1979

Tabular and Graphical Data C-4.9. Cross sections for electron impact ionization of $Ne_2^*(^3\Sigma_u^+)$ metastable excimer.

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
5.0	4.43	15	8.71
6.0	7.20	20	7.72
7.0	8.57	30	6.12
8.0	9.17	40	5.02
9.0	9.40	50	4.23
10.0	9.44		

Cont. Next Column

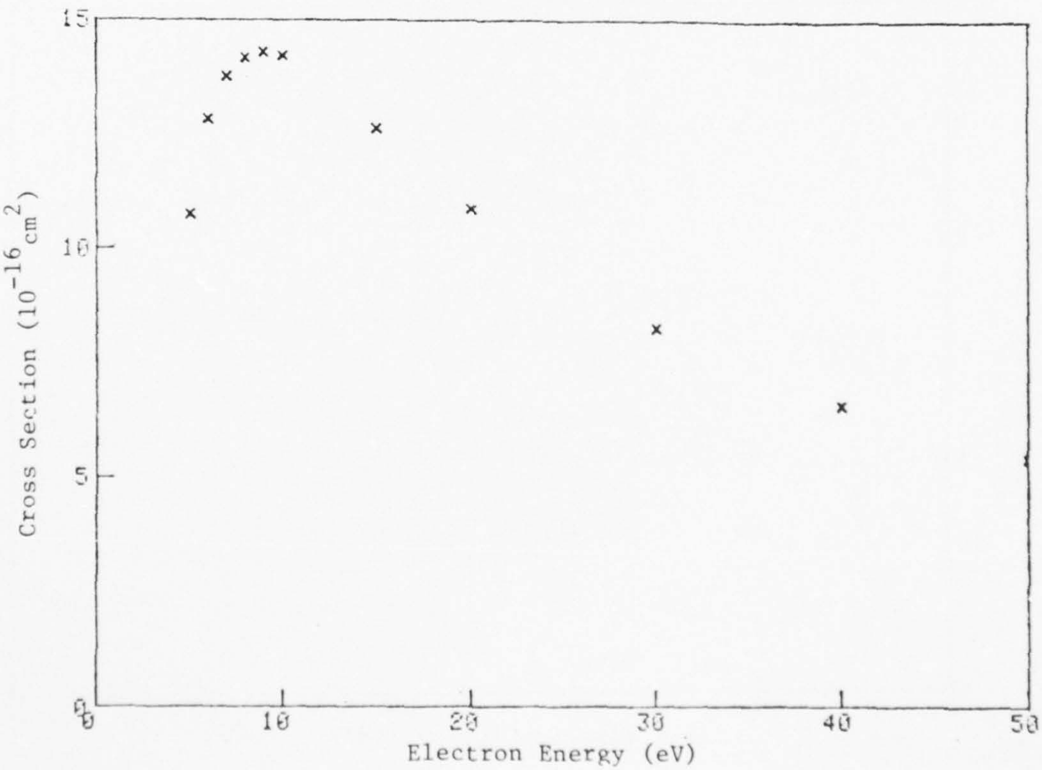


Reference: K. J. McCann, M. R. Flannery, and A Hazi, submitted to Applied Phys. Lett, 1979

Tabular and Graphical Data C-4.10. Cross sections for electron impact ionization of $Ar_2^*(^1\Sigma_u^+)$ metastable excimer.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
5.0	10.74	15	12.66
6.0	12.84	20	10.89
7.0	13.77	30	8.290
8.0	14.19	40	6.590
9.0	14.31	50	5.430
10.0	14.23		

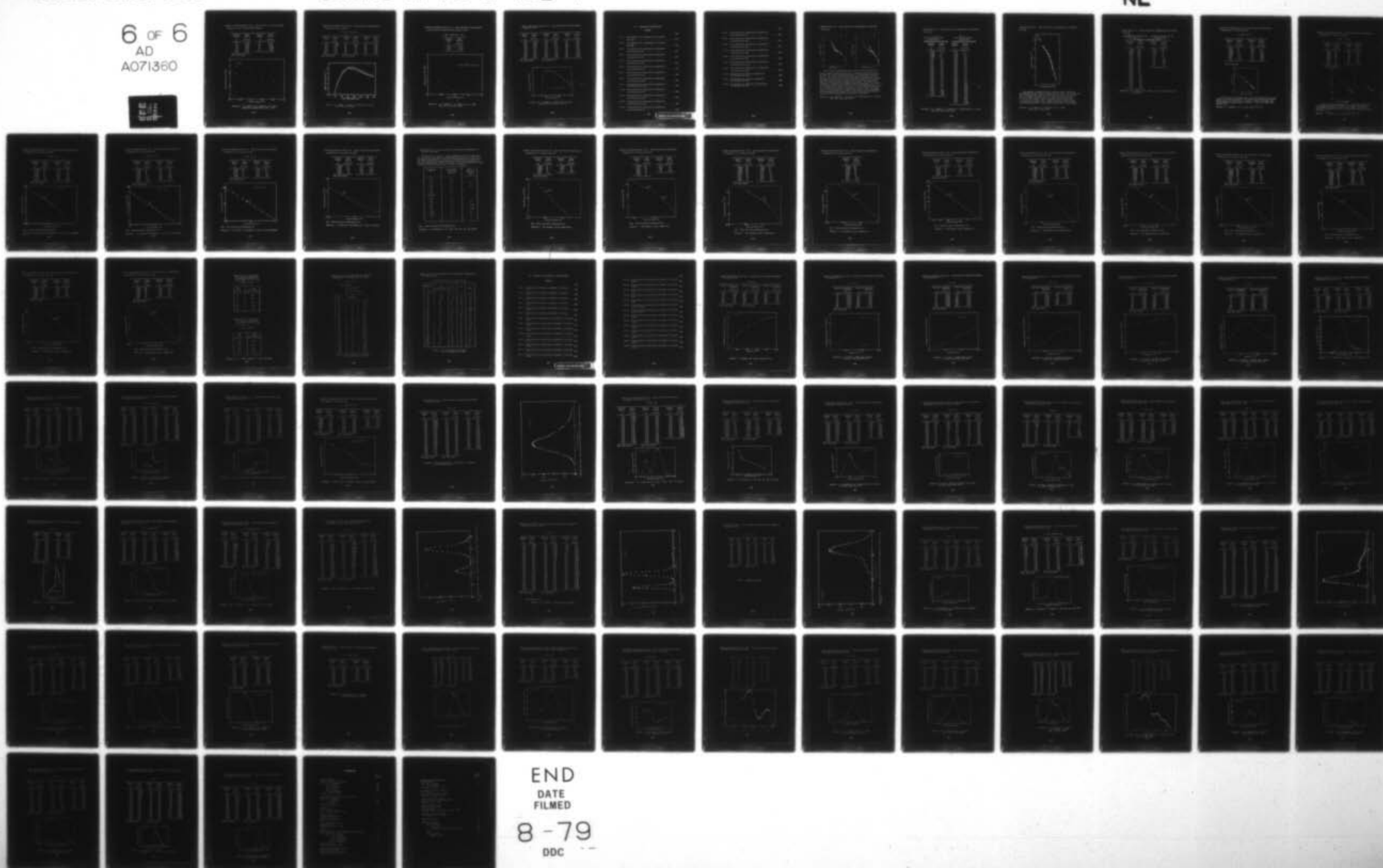
Cont. Next Column



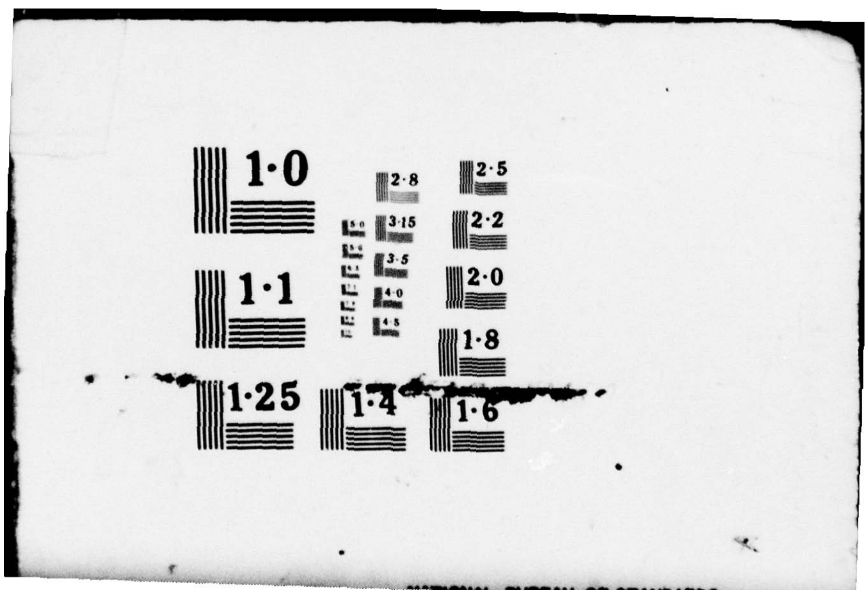
Reference: K. J. McCann, M. R. Flannery, and A. Hazi, submitted to Applied Phys. Lett., 1979

AD-A071 360 ARMY MISSILE RESEARCH AND DEVELOPMENT COMMAND REDSTO--ETC F/G 20/5
COMPILATION OF DATA RELEVANT TO NUCLEAR PUMPED LASERS. VOLUME I--ETC(U)
DEC 78 E W MCDANIEL, M R FLANNERY, E W THOMAS
UNCLASSIFIED DRDMI-H-78-1-VOL-4 NL

6 OF 6
AD
A071360



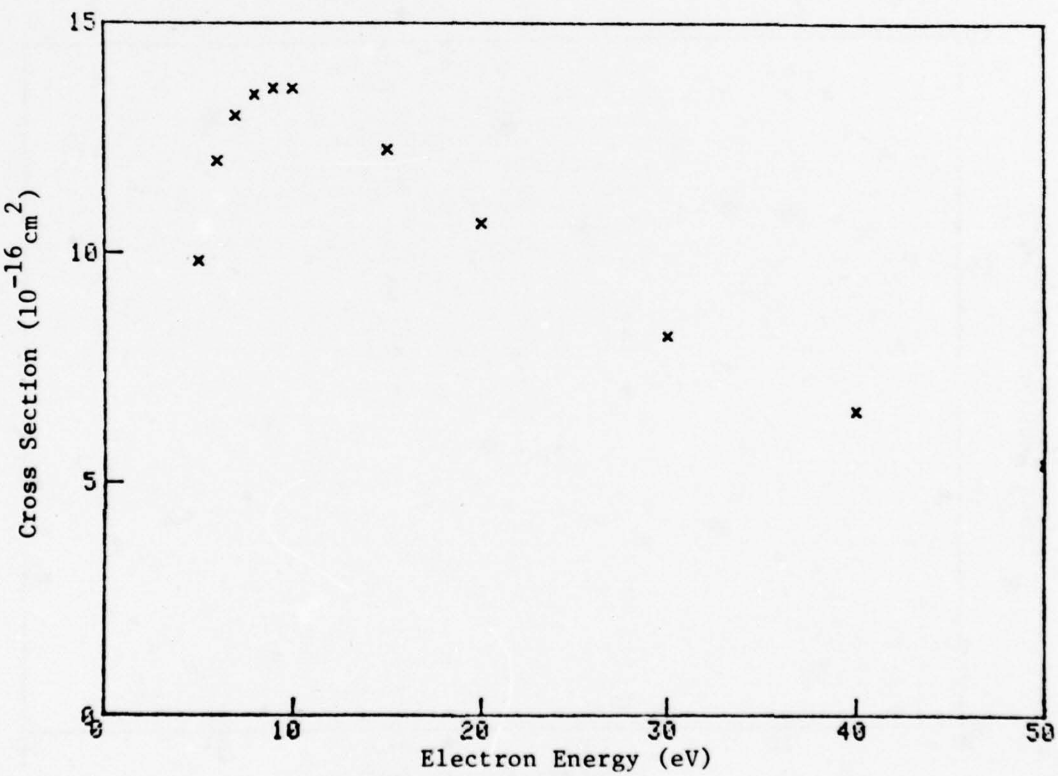
END
DATE
FILMED
8-79
DDC


1·0
2·8
2·5
3·15
2·2
3·5
2·0
1·1
4·0
1·8
1·25
1·4
1·6

Tabular and Graphical Data C-4.11. Cross sections for electron impact ionization of $Ar_2^*(^3\Sigma_u^+)$ metastable excimer.

Electron Energy eV	Cross Section $10^{-16}cm^2$	Electron Energy eV	Cross Section $10^{-16}cm^2$
5.0	9.840	15	12.29
6.0	12.02	20	10.67
7.0	13.00	30	8.200
8.0	13.46	40	6.550
9.0	13.62	50	5.400
10.0	13.61		

Cont. Next Column



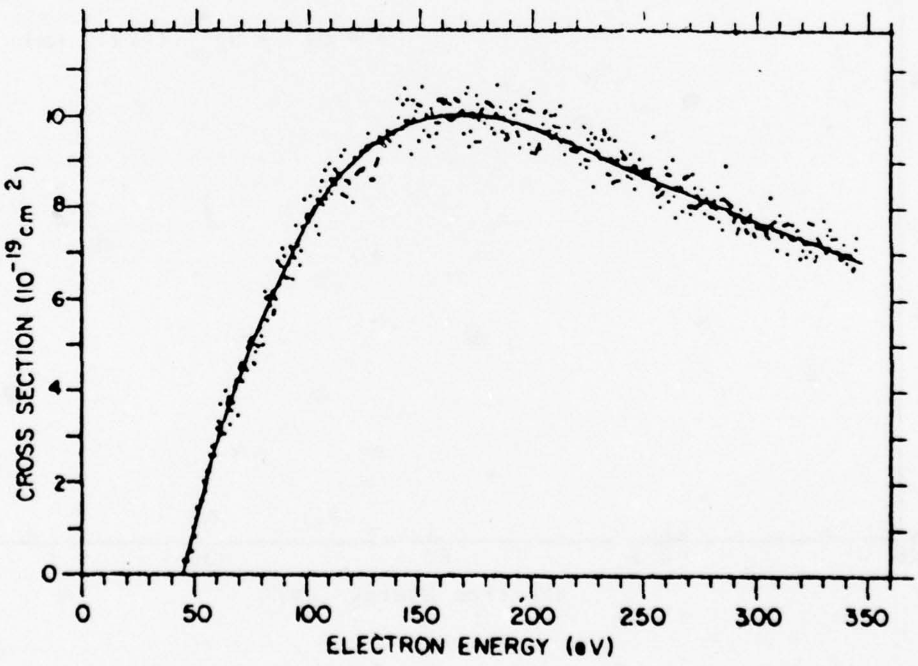
Reference: K. J. McCann, M. R. Flannery, and A. Hazi, submitted to Applied Phys. Lett., 1979

Tabular and Graphical Data C-4.12. Cross sections for dissociative ionization of CO_2 to give C^+.

$e + CO_2 \rightarrow C^+$ (]33.5 nm)

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
45.4	0.0060	118	0.90	214	0.95
49.3	0.093	132	0.95	241	0.90
56.8	0.24	147	0.99	261	0.85
67.5	0.41	158	1.0	287	0.80
78.3	0.54	171	1.0	310	0.76
89.3	0.67	182	1.0	333	0.72
103	0.81	195	0.98	346	0.69

Cont. Next Column   Cont. Next Column

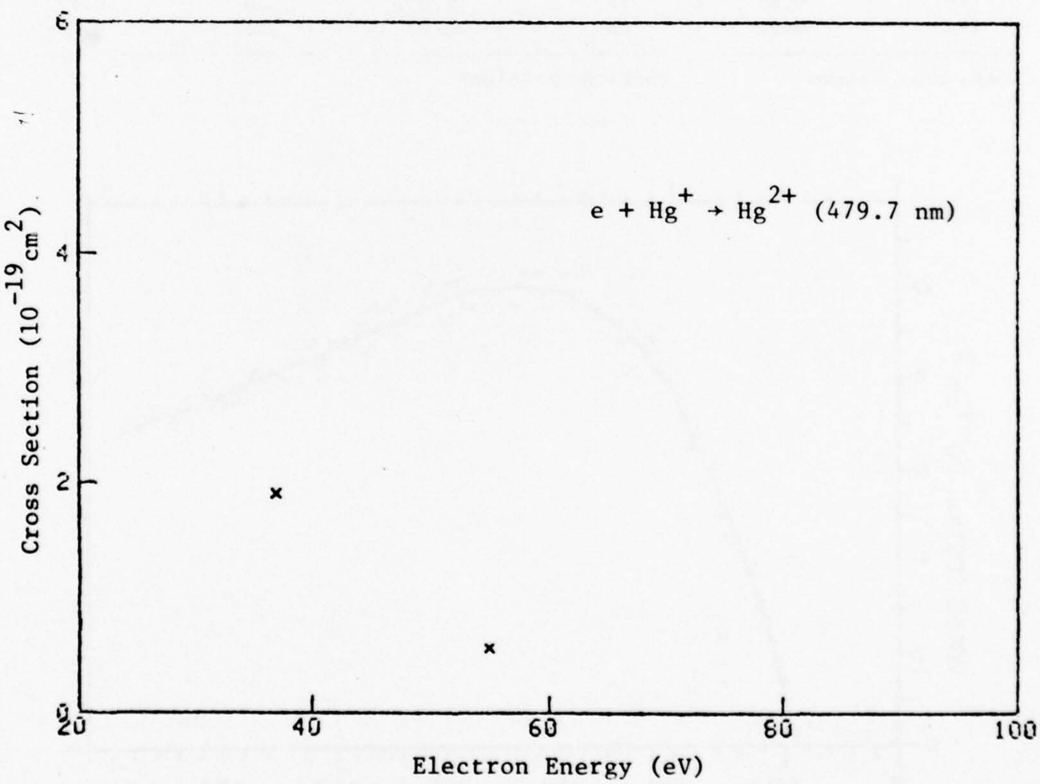


Reference: M. J. Mumma, E. J. Stone, W. L. Borst, and E. C. Zipf, J. Chem. Phys. 57, 68 (1972)

Tabular and Graphical Data C-4.13. Cross sections for simultaneous electron impact ionization and excitation of Hg^+.

$e + Hg^+ \rightarrow Hg^{2+}$ (479.7 nm)

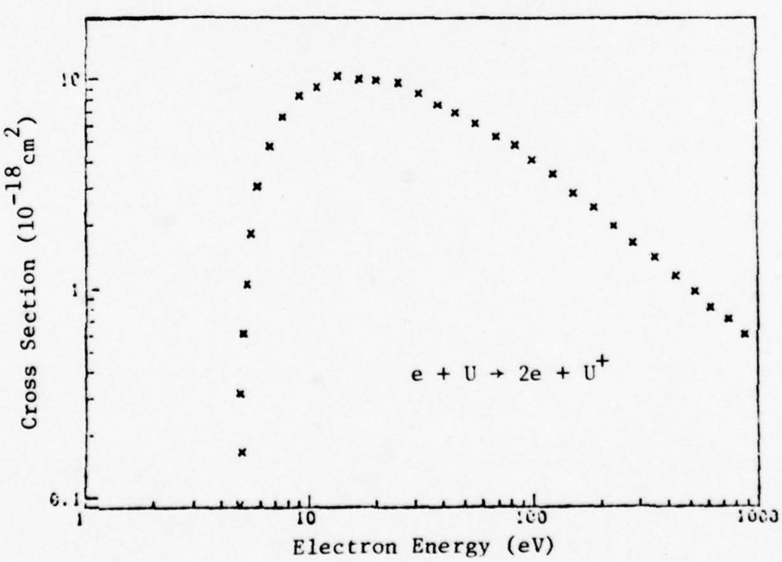
Electron Energy eV	Cross Section $10^{-19} cm^2$
36.8	1.90
55.0	0.564



Reference: R. A. Phaneuf, P. O. Taylor, and G. H. Dunn, Phys. Rev. A 14, 2021 (1976)

Tabular and Graphical Data C-4.14. Cross sections for electron impact ionization of U.

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
4.83	0.0927	13.5	10.6	122	3.58
4.92	0.167	16.9	10.2	151	2.92
4.84	0.317	20.3	10.1	186	2.46
5.05	0.621	25.5	9.79	228	2.02
5.22	1.07	31.2	8.73	279	1.67
5.47	1.86	38.1	7.71	349	1.43
5.82	3.13	45.6	7.03	433	1.16
6.63	4.84	55.7	6.21	525	0.977
7.62	6.71	68.6	5.37	614	0.827
9.06	8.48	83.3	4.89	735	0.727
10.9	9.33	98.8	4.20	881	0.610
Cont. Next Column		Cont. Next Column			

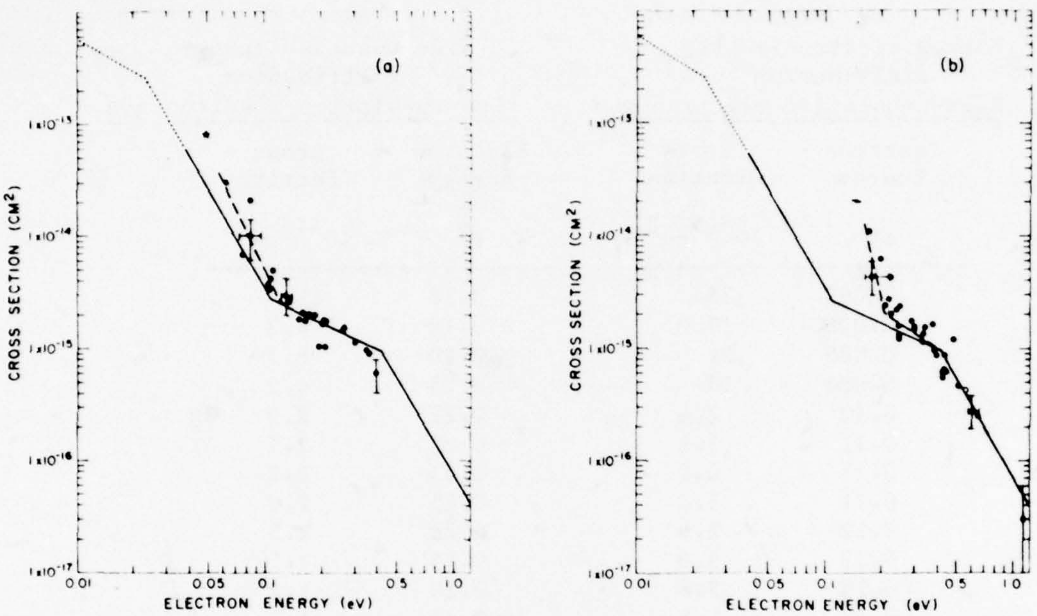


Reference. E. L. Maceda, C. G. Bathke, and G. H. Miley, Trans. Am. Nucl. Soc. 22, 153 (1975)

C-5. ELECTRON-ION RECOMBINATION

CONTENTS

Graphical Data C-5.1. Cross sections for recombination of electrons with H_3O^+.



Electron-H_3O^+ recombination cross section vs energy, taken with a narrow electron energy distribution of a high-resolution electron gun (a), and with a wide energy distribution of a low-resolution electron gun (b). In both (a) and (b) the actual cross-section data are indicated by the points, the solid line represents the deduced cross section, the dashed lines represent a convolution of the deduced cross section with the respective electron energy distributions. The dotted lines represent an extension of the deduced cross section, made to be consistent with the present data, the rate-coefficient measurement of M. T. Leu, M. A. Biondi, and R. Johnsen, Phys. Rev. A 7, 292 (1973) and with theoretical threshold behavior of recombination cross sections. The open circle in (b) represents the average cross section of nine measurements. The star represents the average cross section value obtained from the rate-coefficient measurement of Leu, Biondi, and Johnsen.

Reference: R. A. Heppner, F. L. Walls, W. T. Armstrong, and G. H. Dunn, Phys. Rev. A 13, 1000 (1977).

Tabular Data C-5.1. Cross sections for recombination of electrons with H_3O^+.

(a)
Narrow electron energy distribution
High-resolution electron gun

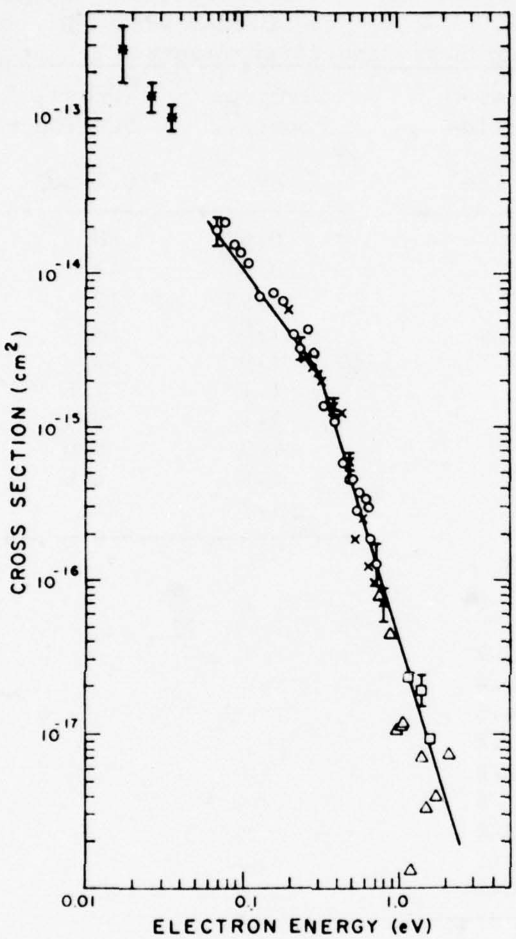
Electron Energy eV	Cross Section $10^{-15}cm^2$
0.062	30
0.078	7.0
0.085	21
0.086	10
0.10	3.6
0.11	3.4
0.11	4.2
0.11	5.0
0.12	2.6
0.13	3.0
0.13	2.6
0.15	1.8
0.16	2.1
0.16	1.8
0.17	2.0
0.18	2.0
0.20	1.6
0.21	1.7
0.19	1.0
0.21	1.0
0.26	1.4
0.26	1.5
0.30	1.1
0.35	0.98
0.36	0.93
0.39	0.62

(b)
Wide electron energy distribution
Low-resolution electron gun

Electron Energy eV	Cross Section $10^{-15}cm^2$
0.18	11
0.18	4.2
0.20	6.1
0.23	4.2
0.22	2.3
0.22	2.7
0.23	2.0
0.25	2.2
0.26	2.3
0.25	1.5
0.26	1.2
0.25	1.3
0.30	1.7
0.31	1.5
0.31	1.4
0.34	1.1
0.34	1.3
0.35	1.5
0.39	1.6
0.39	0.95
0.40	0.86
0.43	0.55
0.43	0.60
0.44	0.64
0.44	0.85
0.49	1.2
0.45	0.60
0.52	0.45
0.62	0.27
0.66	0.25
1.2	0.030

Reference: R. A. Heppner, F. L. Walls, W. T. Armstrong and G. H. Dunn, Phys. Rev. A 13, 1000 (1976)

Graphical Data C-5.2. Cross sections for recombination of electrons with NH_4^+.



Electron-NH_4^+ recombination cross section vs energy. The points are measurements using a high-resolution electron gun in a 0.85 -V well (o); the low-resolution gun (LRG) in a 0.85-V well (x); the LRG in a 0.85-V well with large heating corrections (Δ) (see reference); the LRG in a 1.85-V well (□). The solid line is the deduced cross section from Eq. (6) of the reference. The *'s represent rate-coefficient data of C. M. Huang, M. A. Biondi, and R. Johnsen, Phys. Rev. A 14, 984 (1976) converted approximately to cross sections as discussed in the reference.

Reference: R. D. DuBois, J. B. Jeffries, and G. H. Dunn, Phys. Rev. A, 1314 (1978)

Tabular Data C-5.2. Cross sections for recombination of electrons with NH_4^+.

High-Resolution Electron Gun 0.85-V well (o)		Low-resolution Electron Gun 0.85-V well (□)	
See caption of associated figure			
Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
0.069	190	0.67	80
0.081	200	0.84	49
0.093	140	0.95	12
0.10	130	1.0	12
0.12	100	1.0	13
0.14	69	1.1	1.8
0.17	73	1.2	9.6
0.20	67	1.3	5.6
0.22	25	1.5	6.6
0.24	21	1.7	11
0.26	27		
0.29	20		
0.32	11		
0.36	11		
0.44	5.7		
0.48	4.4		
0.61	4.5		
0.62	1.8		
0.62	2.8		
0.74	1.6		
0.63	3.1		
0.77	1.1		
0.87	0.90		

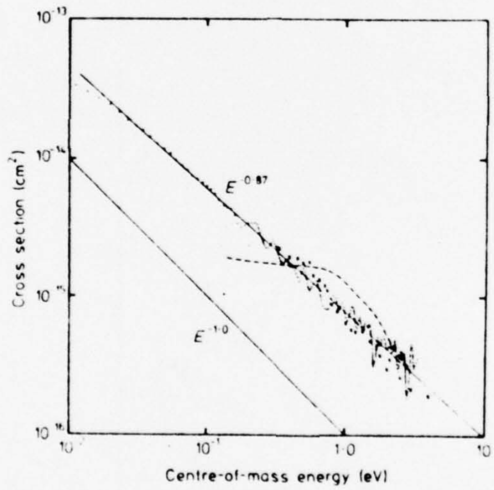
Reference: R. D. DuBois, J. B. Jeffries, and G. H. Dunn, Phys. Rev. A, 1314 (1978).

Tabular and Graphical Data C-5.3. Cross sections for dissociative recombination of electrons with H_2^+.

$$e + H_2^+ \rightarrow H + H$$

Electron Energy eV	Cross Section $10^{-15} cm^2$	Electron Energy eV	Cross Section $10^{-15} cm^2$
0.013	31	0.42	1.7
0.024	24	0.57	1.4
0.036	17	0.72	1.1
0.058	11	0.98	0.82
0.090	7.3	1.7	0.49
0.14	4.8	2.2	0.39
0.22	3.2	3.1	0.30
0.32	2.3	3.5	0.33

Cont. Next Column



The H_2^+ ions are vibrationally hot. The structure detail shown in the figure is not given in the table. Also shown in the figure are the experimental results of B. Peart and K. T. Dolder, J. Phys. B, 236 (1974) (x) and theoretical calculations from C. Bottcher, J. Phys. B <u>9</u>, 2899 (1976) (broken curve).

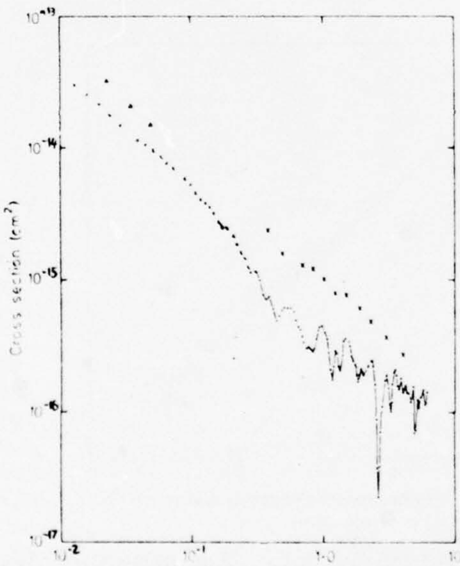
Reference: D. Auerbach et. al., J. Phys. B <u>10</u>, 3797 (1977).

Tabular and Graphical Data C-5.4. Cross sections for dissociative recombination of electrons with H_3^+.

$$e + H_3^+ \rightarrow H + H_2$$

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
0.010	570	0.86	9.1
0.016	390	1.2	5.3
0.032	220	1.5	4.5
0.052	140	2.2	3.3
0.098	79	2.8	3.1
0.15	47	4.1	2.3
0.19	31	4.6	2.1
0.26	21	5.4	2.8
0.47	12		

Cont. Next Column



The H_3^+ ions may be vibrationally hot. The structure detail shown in the figure is not given in the table Also shown in the figure are the experimental results of B. Peart and K. T. Dolder, J. Phys. B 7, 1948 (1974) (x) and of M. T. Leu, M. A. Biondi and R. Johnsen, Phys. Rev A 8, 413 (1973) (Δ).

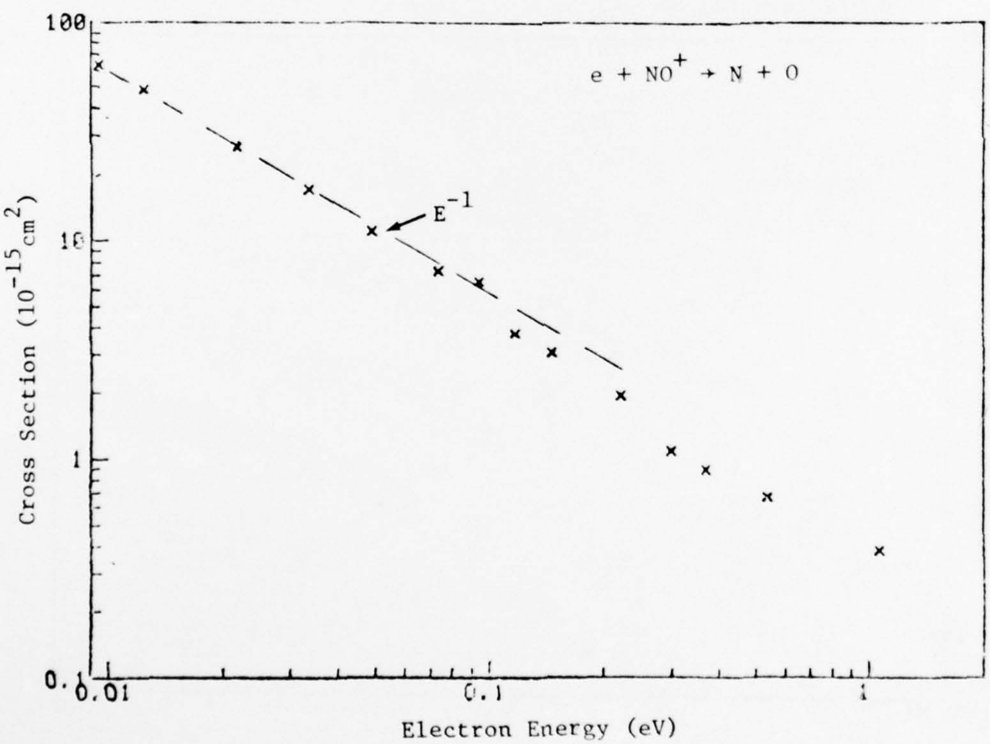
Reference: D. Auerbach et. al., J. Phys. B 10, 3797 (1977).

Tabular and Graphical Data C-5.5. Cross sections for dissociative recombination of electrons with NO^+.

$$e + NO^+ \rightarrow N + O$$

Electron Energy eV	Cross Section 10^{-15} cm^2	Electron Energy eV	Cross Section 10^{-15} cm^2
0.0094	64	0.12	3.8
0.012	49	0.15	3.1
0.022	27	0.22	2.0
0.033	17	0.30	1.1
0.049	11	0.37	0.89
0.073	7.3	0.54	0.67
0.094	6.6	1.1	0.38

Cont. Next Column



Note: These ions may be vibrationally hot.

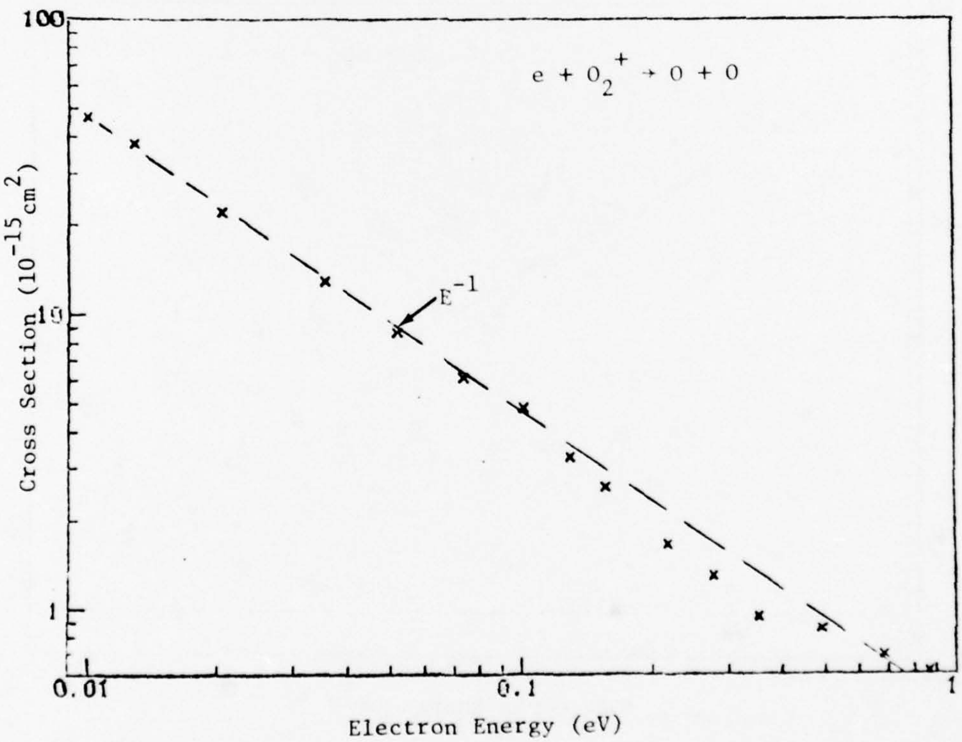
Reference: P. M. Mul and J. Wm. McGowan, J. Phys. B (to be published).

Tabular and Graphical Data C-5.6. Cross sections for dissociative recombination of electrons with O_2^+.

$$e + O_2^+ \rightarrow O + O$$

Electron Energy eV	Cross Section $10^{-15} cm^2$	Electron Energy eV	Cross Section $10^{-15} cm^2$
0.0099	47	0.16	2.6
0.013	38	0.22	1.7
0.021	22	0.28	1.3
0.036	13	0.35	0.95
0.052	8.7	0.49	0.86
0.074	6.1	0.68	0.70
0.10	4.8	0.87	0.61
0.13	3.3		

Cont. Next Column



Note: These ions may be vibrationally hot.

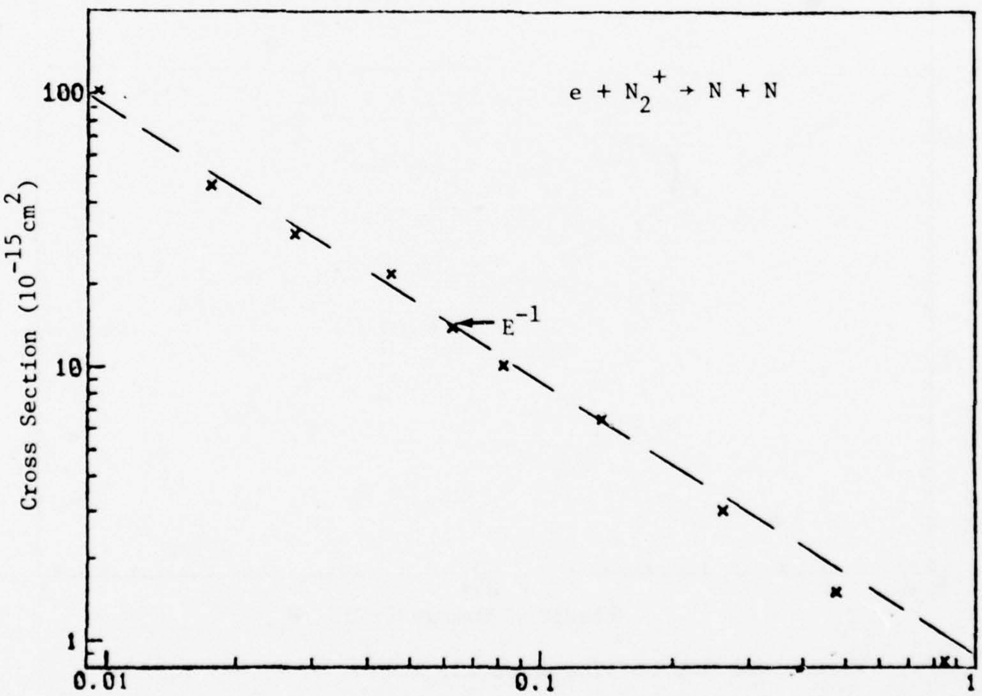
Reference: P. M. Mul and J. Wm. McGowan, J. Phys. B (to be published).

Tabular and Graphical Data C-5.7. Cross sections for dissociative recombination of electrons with N_2^+.

$$e + N_2^+ \rightarrow N + N$$

Electron Energy eV	Cross Section $10^{-15} cm^2$	Electron Energy eV	Cross Section $10^{-15} cm^2$
0.0095	100	0.082	10
0.018	47	0.14	6.6
0.027	31	0.26	3.0
0.045	22	0.48	1.5
0.063	14	0.85	0.84

Cont. Next Column



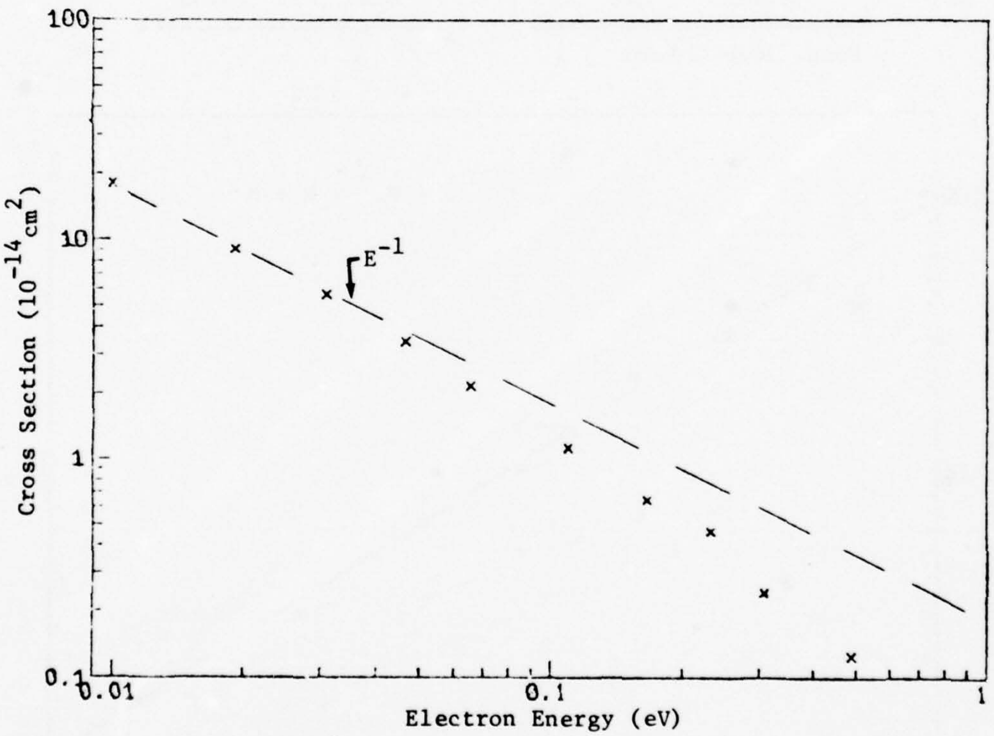
Note: These ions may be vibrationally hot.

Reference: P. M. Mul and J. Wm. McGowan, J. Phys. B (to be published).

Tabular and Graphical Data C-5.8. Cross sections for dissociative recombination of electrons with N_2H^+.

Electron Energy eV	Cross Section $10^{-14} cm^2$	Electron Energy eV	Cross Section $10^{-14} cm^2$
0.0100	18	0.11	1.1
0.019	9.0	0.17	0.64
0.031	5.6	0.23	0.46
0.047	3.4	0.31	0.24
0.066	2.2	0.49	0.13

Cont. Next Column



Note: These ions may be vibrationally hot.

Reference: P. M. Mul and J. Wm. McGowan, Ap. J. 227, L157 (1979).

Tabular Data C-5.9. Cross sections for dissociative recombination of electrons with ions.

The data in C - 5.10 to C - 5.20 are summarized in the following table. The electron-ion dissociative recombination was measured in an electron-ion merged-beam experiment. The cross sections at 0.01 eV are given below. The cross sections have an approximate 1/E electron-energy dependence at electron energies below 0.08 eV. The onset of deviation indicates the energy at which the cross section deviates from the 1/E behavior.

Recombining Ion	Cross Section at 0.01 eV ($10^{-13} cm^2$)	Onset of Deviation from 1/E (eV)
OH^+	0.2	
H_2O^+	1.8	0.1
H_3O^+	1.5	0.1
C_2^+	1.4	
CH^+ (excited)	1.1	
CH_2^+	1.2	
CH_3^+	1.7	0.1
CH_4^+	1.3	0.07
CH_5^+	1.5	0.08
$C_2H_2^+$	1.4	0.1
$C_2H_3^+$	2.2	0.1

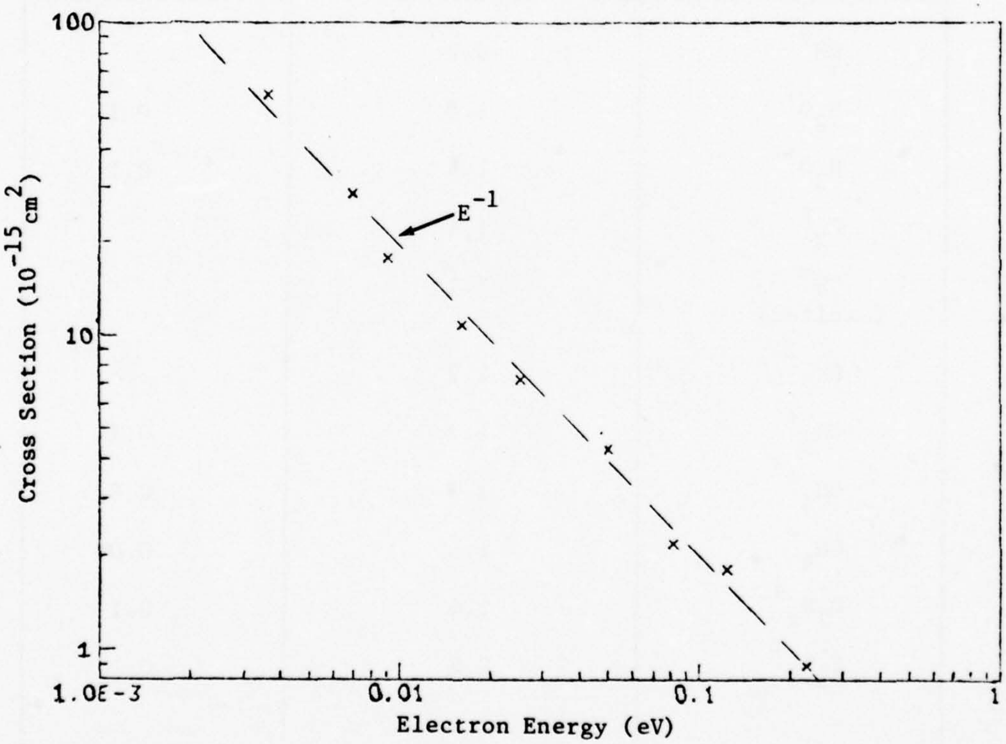
Note: These ions may be vibrationally hot.

Reference: J. Wm. McGowan et. al., Phys. Rev. Lett. 42, 373 (1979).

Tabular and Graphical Data C-5.10. Cross sections for dissociative recombination of electrons with OH^+.

Electron Energy eV	Cross Section $10^{-15} cm^2$	Electron Energy eV	Cross Section $10^{-15} cm^2$
0.0036	59	0.050	4.3
0.0069	29	0.082	2.1
0.0091	18	0.12	1.8
0.016	11	0.23	0.88
0.025	7.2		

Cont. Next Column

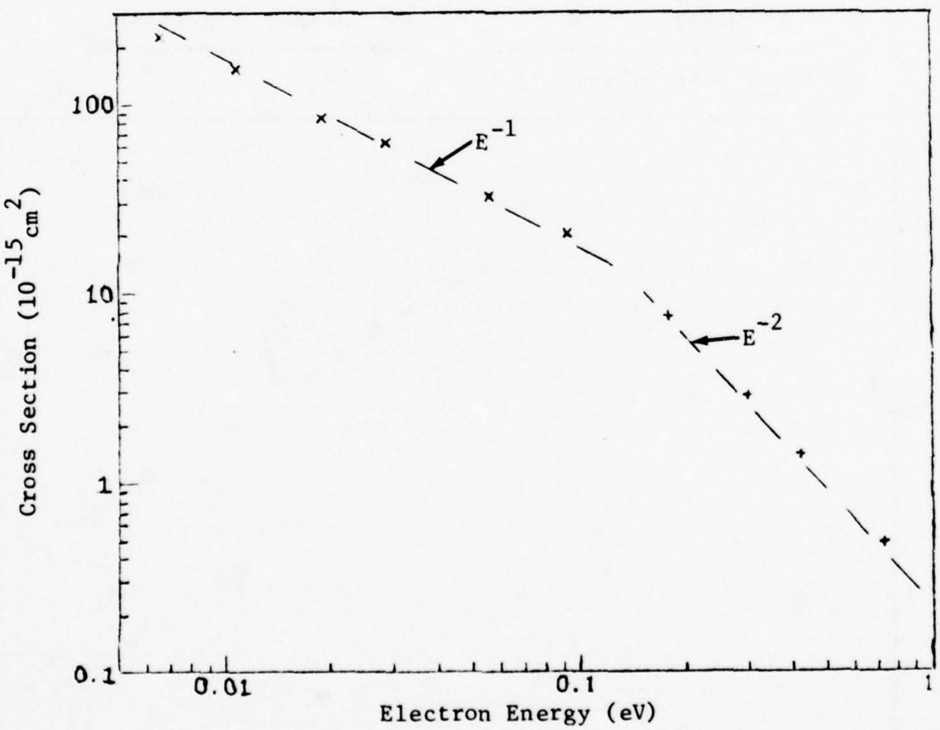


Note: These ions may be vibrationally hot.

Reference: J. Wm. McGowan, private communication.

Tabular and Graphical Data C-5.11. Cross sections for dissociative recombination of electrons with H_2O^+.

Electron Energy eV	Cross Section $10^{-15}cm^2$	Electron Energy eV	Cross Section $10^{-15}cm^2$
0.0066	230	0.18	7.5
0.011	150	0.30	2.9
0.019	84	0.42	1.4
0.029	62	0.72	0.48
0.056	32		
0.093	20		



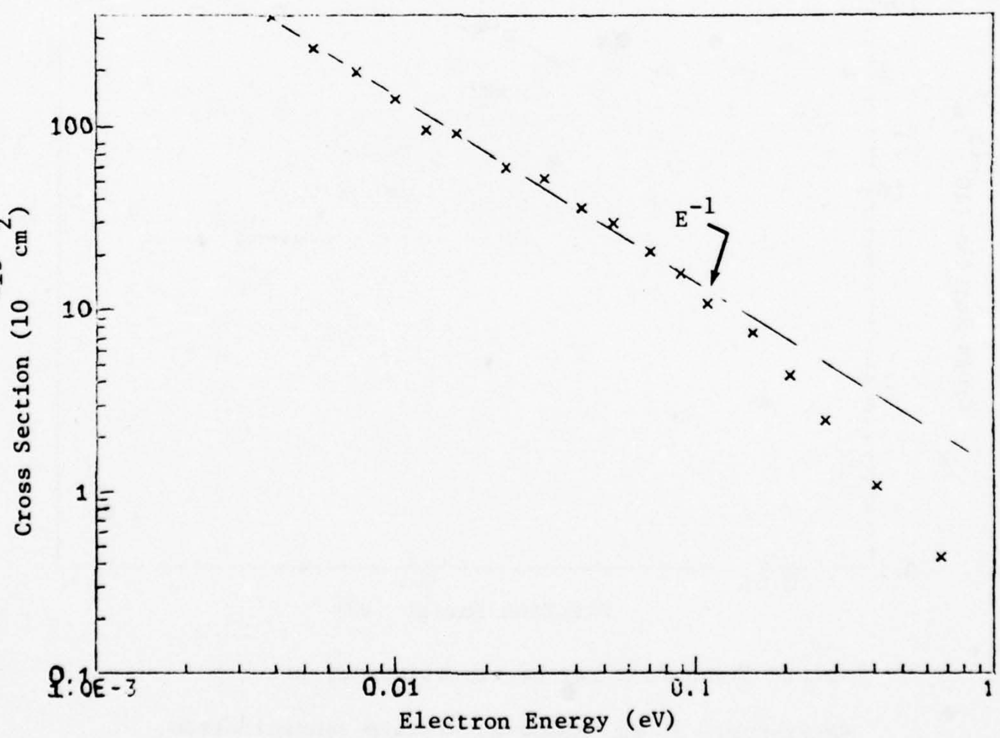
Note: These ions may be vibrationally hot.

Reference: J. Wm. McGowan, private communication.

Tabular and Graphical Data C-5.12. Cross sections for dissociative recombination of electrons with H_3O^+.

Electron Energy eV	Cross Section $10^{-15}cm^2$	Electron Energy eV	Cross Section $10^{-15}cm^2$
0.0039	390	0.053	30
0.0053	260	0.071	21
0.0074	200	0.090	16
0.0099	140	0.11	11
0.013	94	0.16	7.4
0.016	90	0.21	4.3
0.023	59	0.28	2.4
0.031	51	0.41	1.1
0.042	36	0.67	0.44

Cont. Next Column

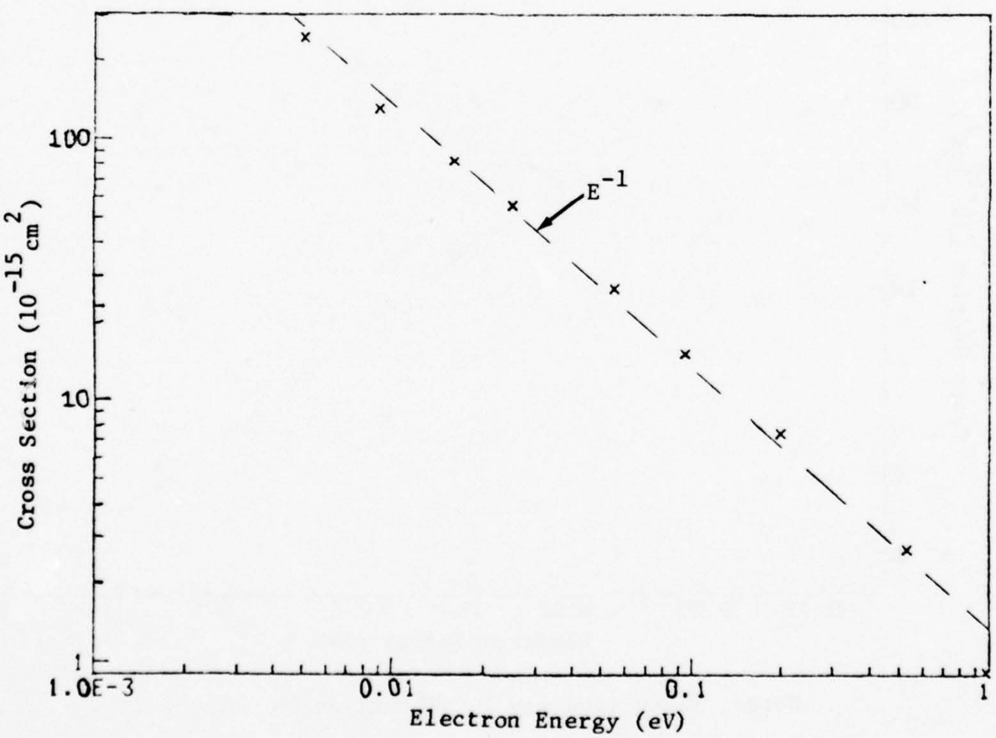


Note: These ions may be vibrationally hot.

Reference: J. Wm. McGowan, private communication.

Tabular and Graphical Data C-5.13. Cross sections for dissociative recombination of electrons with C_2^+.

Electron Energy eV	Cross Section $10^{-15}cm^2$
0.0051	240
0.0090	130
0.016	83
0.025	56
0.055	27
0.096	15
0.20	7.6
0.53	2.7
0.98	0.93



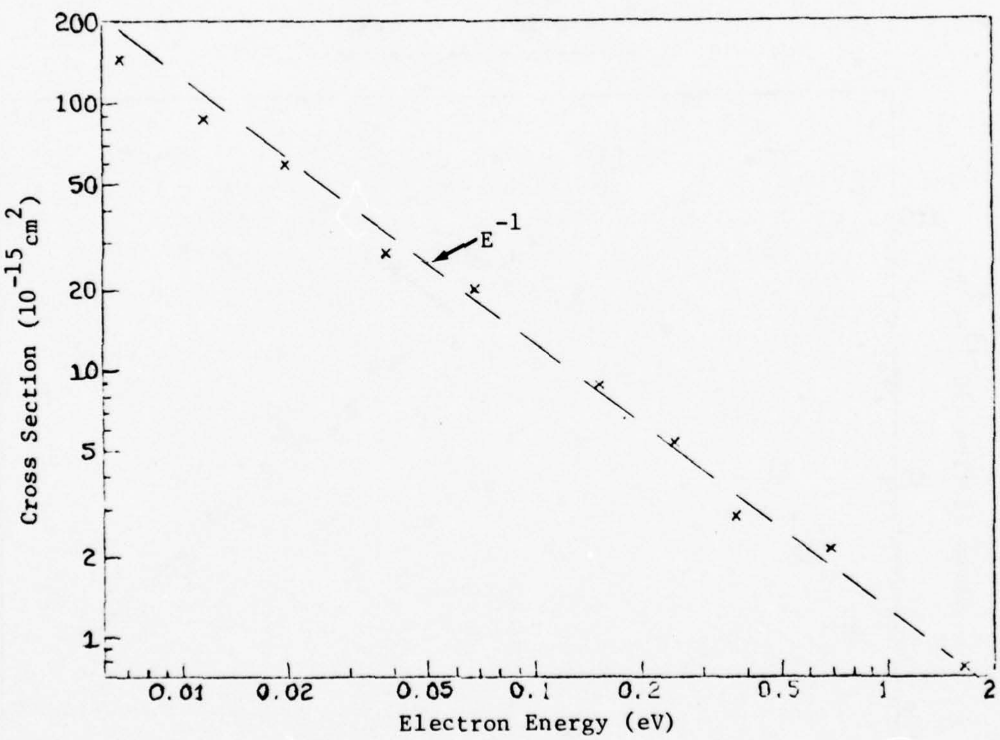
Note: These ions may be vibrationally hot.

Reference: J. Wm. McGowan, private communication.

Tabular and Graphical Data C-5.14. Cross sections for dissociative recombination of electrons with CH^+.

Electron Energy eV	Cross Section $10^{-15}cm^2$	Electron Energy eV	Cross Section $10^{-15}cm^2$
0.0067	140	0.15	8.7
0.012	87	0.25	5.3
0.020	59	0.37	2.8
0.038	27	0.69	2.1
0.068	20	1.7	0.75

Cont. Next Column



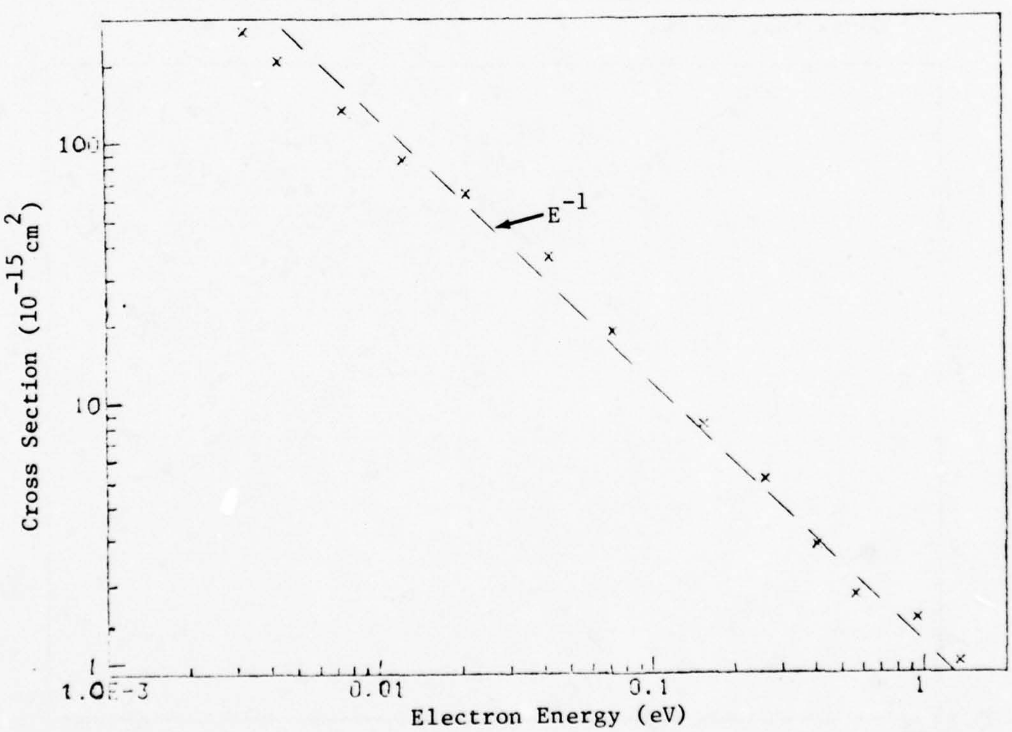
Note: These ions may be vibrationally hot.

Reference: J. Wm. McGowan, private communication.

Tabular and Graphical Data C-5.15. Cross sections for dissociative recombination of electrons with CH_2^+.

Electron Energy eV	Cross Section $10^{-15} cm^2$	Electron Energy eV	Cross Section $10^{-15} cm^2$
0.0032	270	0.15	8.2
0.0044	210	0.26	5.0
0.0075	130	0.41	2.8
0.012	86	0.56	1.8
0.021	64	0.94	1.4
0.042	36	1.4	0.98
0.072	19		

Cont. Next Column



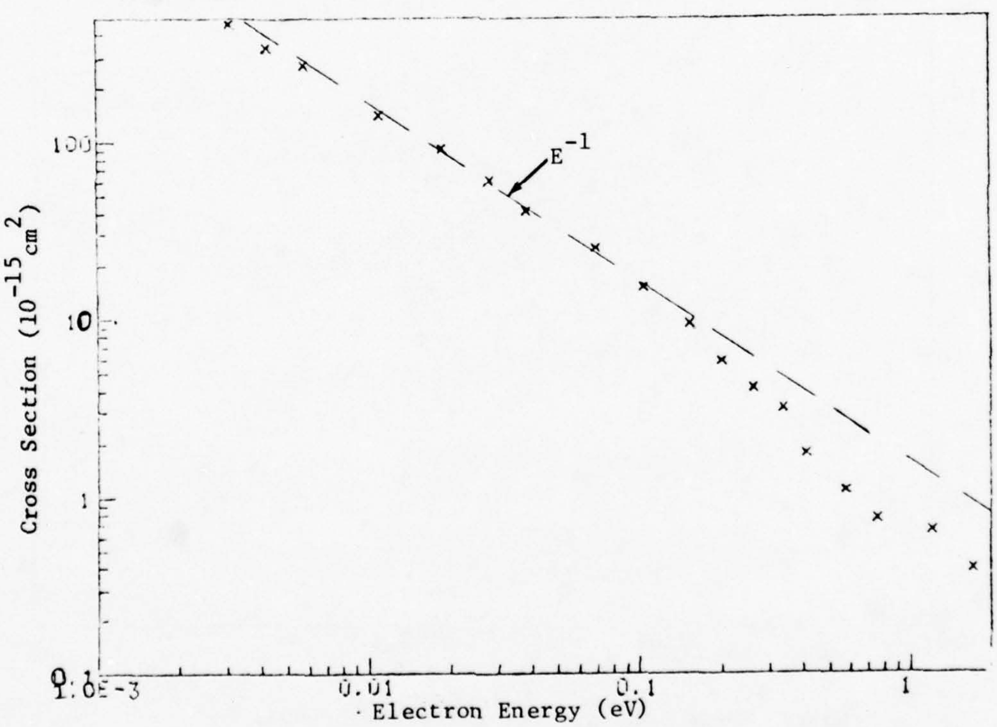
Note: These ions may be vibrationally hot.

Reference: J. Wm. McGowan, private communication.

Tabular and Graphical Data C-5.16. Cross sections for dissociative recombination of electrons with CH_3^+.

Electron Energy eV	Cross Section $10^{-15}cm^2$	Electron Energy eV	Cross Section $10^{-15}cm^2$
0.0031	470	0.15	9.5
0.0042	340	0.20	5.8
0.0058	270	0.26	4.1
0.011	140	0.34	3.2
0.019	92	0.41	1.8
0.028	61	0.58	1.1
0.039	41	0.75	0.75
0.070	25	1.2	0.64
0.10	15	1.7	0.39

Cont. Next Column



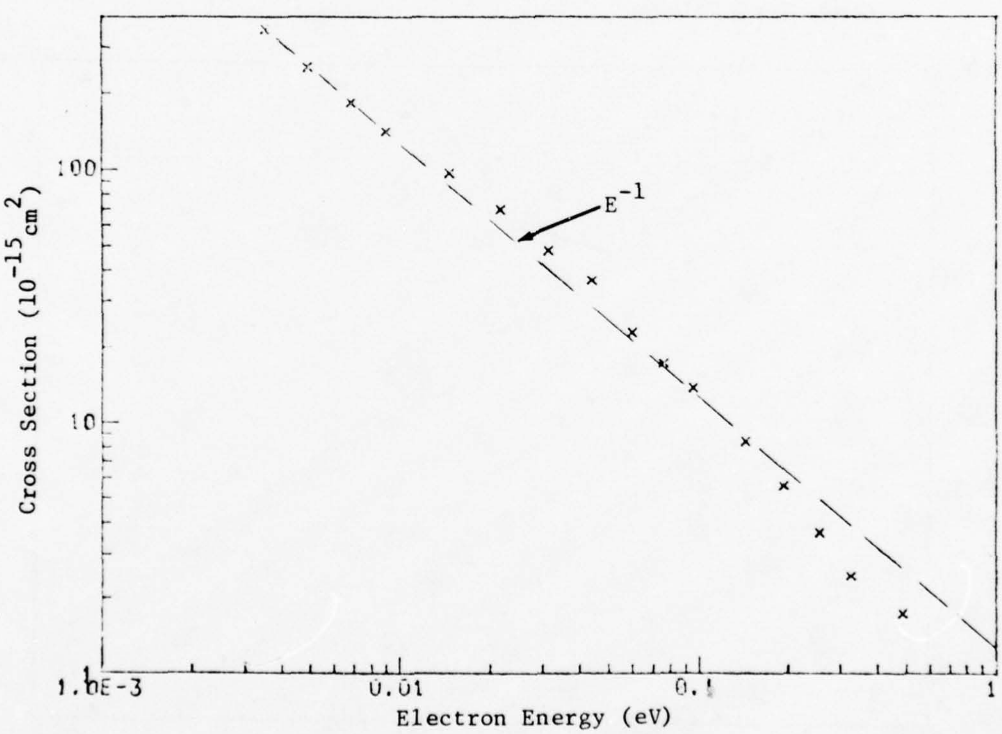
Note: These ions may be vibrationally hot.

Reference: J. Wm. McGowan, private communication.

Tabular and Graphical Data C-5.17. Cross sections for dissociative recombination of electrons with CH_4^+.

Electron Energy eV	Cross Section $10^{-15}cm^2$	Electron Energy eV	Cross Section $10^{-15}cm^2$
0.0035	360	0.060	23
0.0049	250	0.076	17
0.0068	180	0.095	14
0.0090	140	0.14	8.4
0.015	97	0.19	5.5
0.022	70	0.25	3.6
0.031	48	0.32	2.4
0.044	37	0.48	1.7

Cont. Next Column



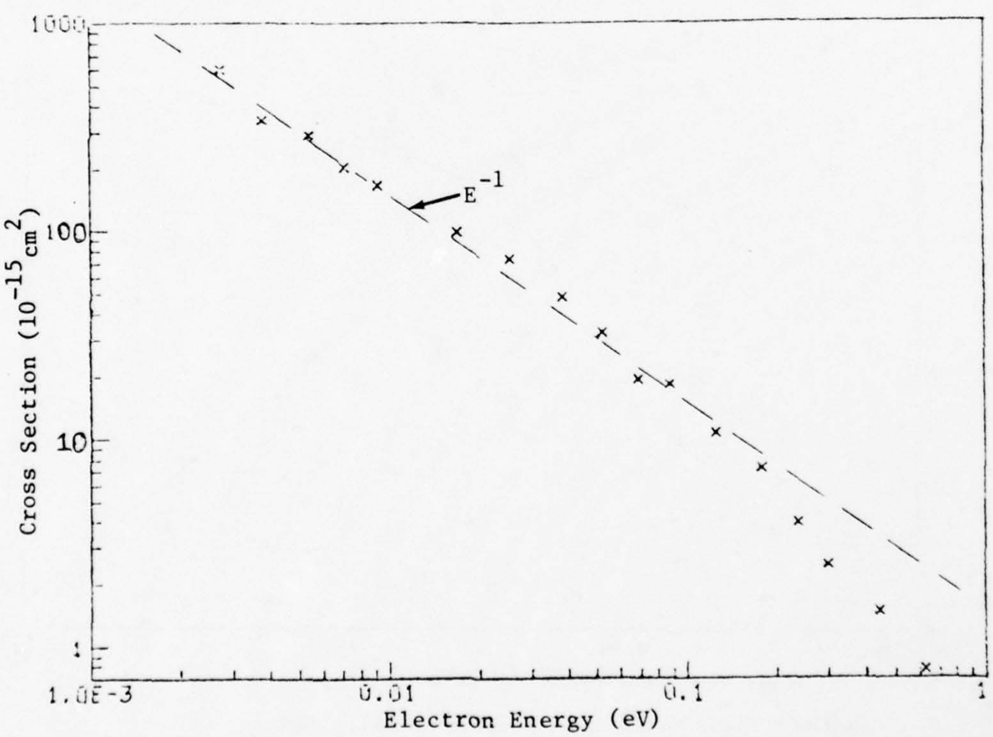
Note: These ions may be vibrationally hot.

Reference: J. Wm. McGowan, private communication.

Tabular and Graphical Data C-5.18. Cross sections for dissociative recombination of electrons with CH_5^+.

Electron Energy eV	Cross Section $10^{-15} cm^2$	Electron Energy eV	Cross Section $10^{-15} cm^2$
0.0027	600	0.069	19
0.0038	340	0.088	18
0.0054	290	0.13	11
0.0071	200	0.18	7.2
0.0092	170	0.24	3.9
0.017	99	0.30	2.4
0.025	73	0.44	1.5
0.038	48	0.63	0.77
0.052	32		

Cont. Next Column



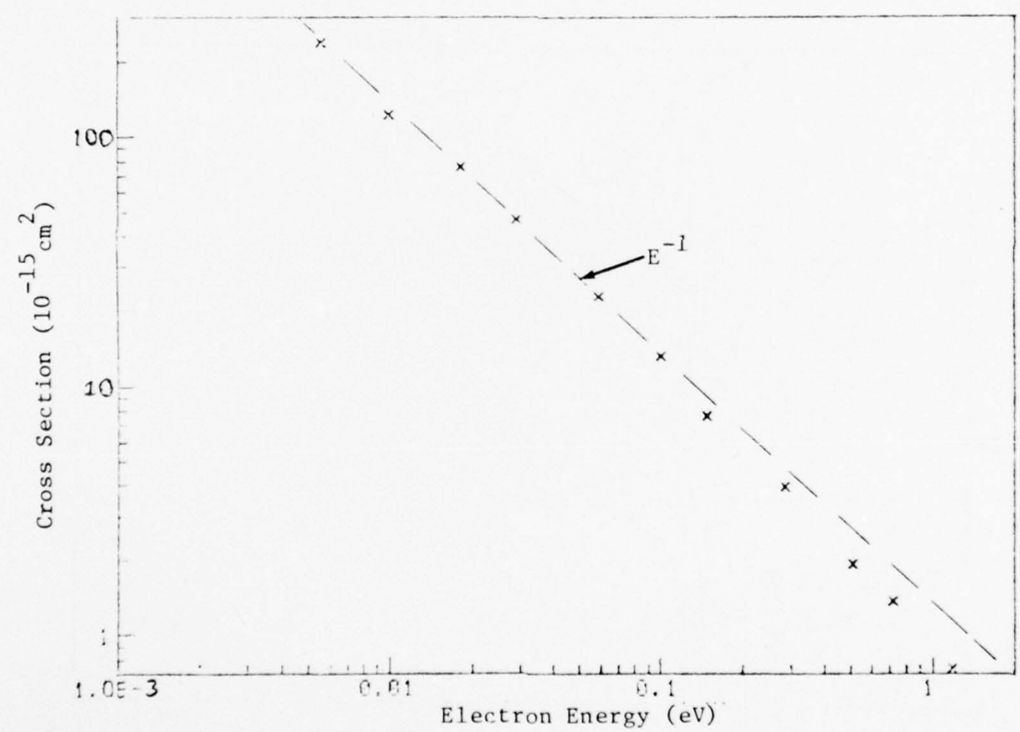
Note: These ions may be vibrationally hot.

Reference: J. Wm. McGowan, private communication.

Tabular and Graphical Data C-5.19. Cross sections for dissociative recombination of electrons with $C_2H_2^+$.

Electron Energy eV	Cross Section $10^{-15}cm^2$	Electron Energy eV	Cross Section $10^{-15}cm^2$
0.0055	240	0.15	7.6
0.0099	120	0.29	3.9
0.018	76	0.51	1.9
0.029	47	0.71	1.4
0.060	23	1.2	0.73
0.10	13		

Cont. Next Column



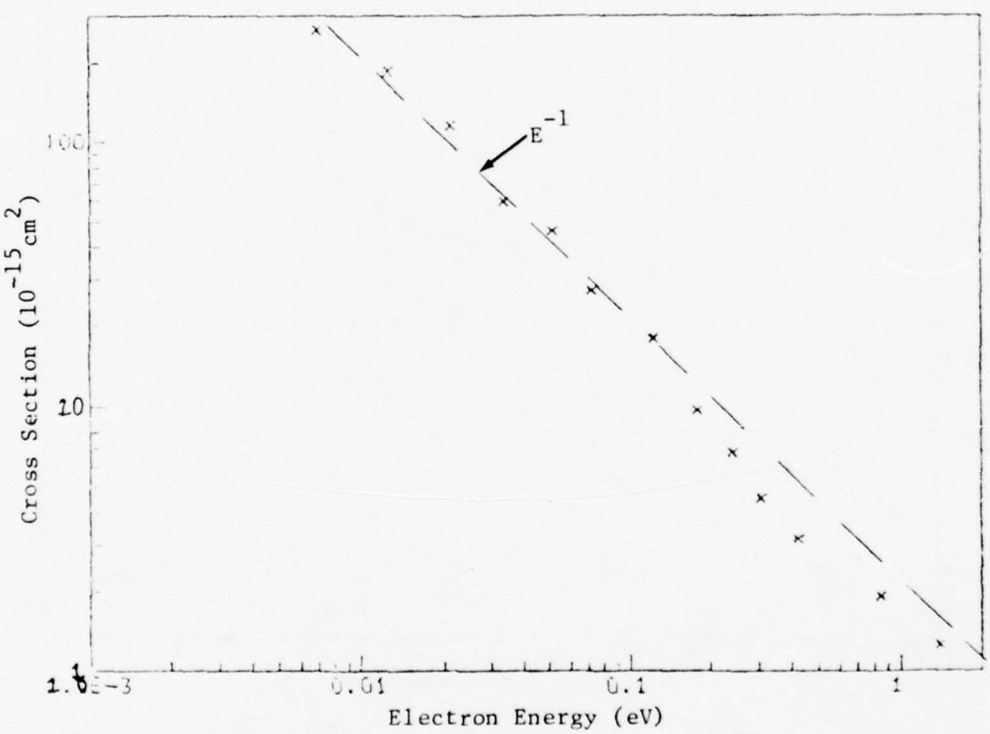
Note: These ions may be vibrationally hot.

Reference: J. Wm. McGowan, private communication.

Tabular and Graphical Data C-5.20. Cross sections for dissociative recombination of electrons with $C_2H_3^+$.

Electron Energy eV	Cross Section $10^{-15}cm^2$	Electron Energy eV	Cross Section $10^{-15}cm^2$
0.0070	260	0.18	9.7
0.013	190	0.24	6.7
0.022	120	0.31	4.5
0.034	60	0.42	3.2
0.052	46	0.84	1.9
0.072	27	1.4	1.3
0.12	18		

Cont. Next Column



Note: These ions may be vibrationally hot.

Reference: J. Wm. McGowan, private communication.

Tabular C-5.21a. Coefficients for radiative recombination of electrons with ions (α_{rad}) at T = 100 K.

$$e + X^{n+} \rightarrow X^{(n-1)+}$$

Ion (X^{n+})	α_{rad} (10^{-12} cm^3/sec)
C^+	8.83
N^+	8.11
O^+	7.49
Ne^+	7.00
Ar^+	7.26

Tabular C-5.21b. Coefficients for radiative recombination of electrons with ions (α_{rad}) at T = 10^4K.

$$e + X^{n+} \rightarrow X^{(n-1)+}$$

Ion (X^{n+})	α_{rad} (10^{-13} cm^3/sec)
Ar^{+1}	3.30
Ar^{+2}	24.5
Ar^{+3}	43.1
Ar^{+4}	74.0

Reference: R. J. Gould, Astrophys. J. 219, 250 (1978)

Tabular Data C-5.22. Coefficients for radiative recombination of electrons with ions (α_{rad}).

$$e + X^{n+} \rightarrow X^{(n-1)+}$$

General formula:

$$\alpha_{rad} = A_{rad} \ (T_e/10^4)^{-\eta}$$

$$\alpha_{rad} = (T_e = 10^4) = A_{rad}$$

Ion (X^{n+})	A_{rad} (10^{-12} cm^3/sec)	η
C^{+1}	.47	.624
C^{+2}	2.3	.645
C^{+3}	3.2	.770
C^{+4}	7.5	.817
C^{+5}	17.0	.721
N^{+1}	0.41	0.608
N^{+2}	2.2	0.639
N^{+3}	50	0.676
N^{+4}	6.5	0.743
N^{+5}	0.15	0.850
N^{+6}	0.29	0.750
O^{+1}	0.31	0.678
O^{+2}	2.0	0.646
O^{+3}	5.1	0.666
O^{+4}	9.6	0.670
O^{+5}	1.2	0.779
O^{+6}	23	0.802
O^{+7}	41	0.742
Ne^{+1}	0.22	0.759
Ne^{+2}	1.5	0.693
Ne^{+3}	4.4	0.675
Ne^{+4}	9.1	0.668
Ne^{+5}	15	0.684
Ne^{+6}	23	0.704

Reference: S. M. V. Aldrovandi and D. Pequignot, Astron. and Astrophys. 25, 137 (1973)

Tabular Data C-5.23. Coefficients for dielectronic recombination of electrons with ions.

$$\alpha_{di} = A_{di}\ T_e^{-3/2} \exp(-T_0/T_e)(1 + B_{di} \exp(-T_1/T_e))$$

Recombining Ion	A_{di} $10^{-3}cm^3sec^{-1}{}^\circ K^{3/2}$	T_0 $10^5\ {}^\circ K$	B_{di}	T_1 $10^5\ {}^\circ K$
He^{+1}	1.9	4.7	0.3	0.94
C^{+1}	0.69	1.1	3.0	0.49
C^{+2}	7.0	.15	0.5	2.3
C^{+3}	3.8	.91	2.0	3.7
C^{+4}	48	34	0.2	5.1
C^{+5}	48	41	0.2	7.6
N^{+1}	.52	1.3	3.8	0.48
N^{+2}	1.7	1.4	4.1	0.68
N^{+3}	12	1.8	1.4	3.8
N^{+4}	5.5	1.1	3.0	5.9
N^{+5}	76	47	0.2	7.2
N^{+6}	66	54	0.2	9.8
O^{+1}	1.4	1.7	2.5	1.3
O^{+2}	1.4	1.7	3.3	.58
O^{+3}	2.8	1.8	6.0	.91
O^{+4}	17	2.2	2.0	5.9
O^{+5}	7.1	1.3	3.2	8.0
O^{+6}	110	62	0.2	9.5
O^{+7}	86	70	0.2	13
Ne^{+1}	1.3	3.1	1.9	.15
Ne^{+2}	3.1	2.9	0.6	1.7
Ne^{+3}	7.5	2.6	0.7	4.5
Ne^{+4}	5.7	2.4	4.3	1.7
Ne^{+5}	10	2.4	4.8	3.5
Ne^{+6}	40	2.9	1.6	11

Reference: S. M. V. Aldrovandi and D. Pequignot, Astron. and Astrophys. 25, 137 (1973).

C-6. NEGATIVE ION FORMATION BY ELECTRON IMPACT

CONTENTS

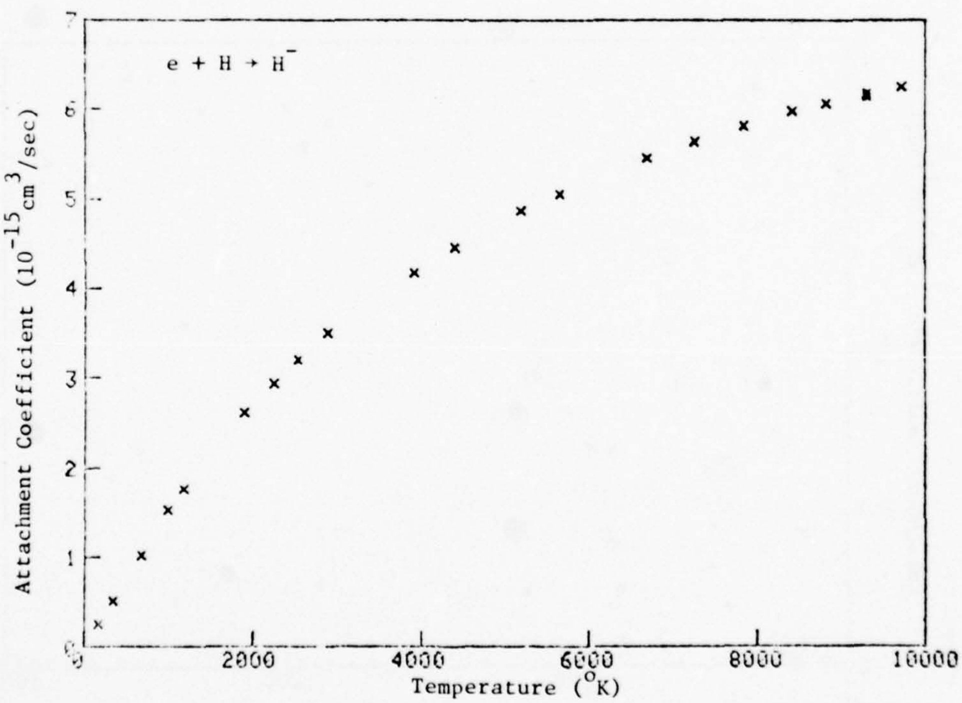
Page

Tabular and Graphical Data C-6.1. Coefficient for radiative attachment of electrons to H.

$$e + H \rightarrow H^-$$

Temperature ^oK	Attachment Coefficient $10^{-15}cm^3/sec$	Temperature ^oK	Attachment Coefficient $10^{-15}cm^3/sec$	Temperature ^oK	Attachment Coefficient $10^{-15}cm^3/sec$
164	0.248	2530	3.21	7250	5.64
339	0.505	2890	3.51	7840	5.82
672	1.02	3920	4.18	8410	5.98
985	1.52	4400	4.46	8820	6.07
1170	1.76	5190	4.88	9300	6.19
1880	2.61	5650	5.06	9300	6.14
2240	2.93	6690	5.46	9720	6.27

Cont. Next Column   Cont. Next Column



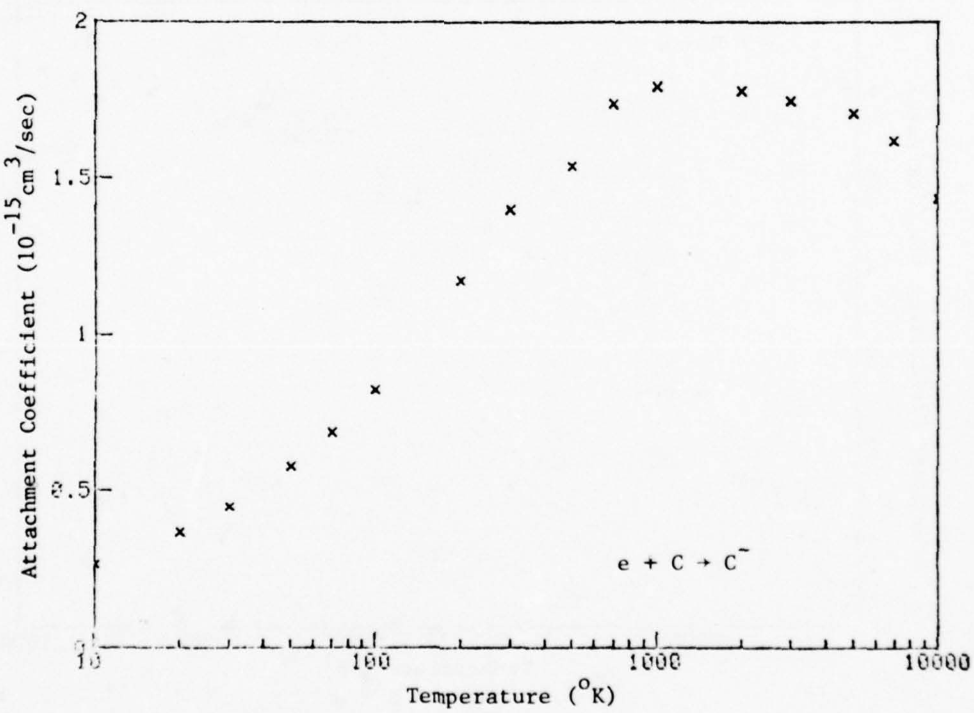
Reference: J. Callaway, Phys. Letters A 48, 359 (1974)

Tabular and Graphical Data C-6.2. Coefficient for radiative attachment of electrons to C.

$$e + C \rightarrow C^-$$

Temperature deg K	Attachment Coefficient $10^{-15}cm^3/sec$	Temperature deg K	Attachment Coefficient $10^{-15}cm^3/sec$
10	0.2610	500	1.541
20	0.3650	700	1.742
30	0.4460	1000	1.795
50	0.5770	2000	1.780
70	0.6850	3000	1.750
100	0.8240	5000	1.709
200	1.174	7000	1.624
300	1.402	10000	1.438

Cont. Next Column



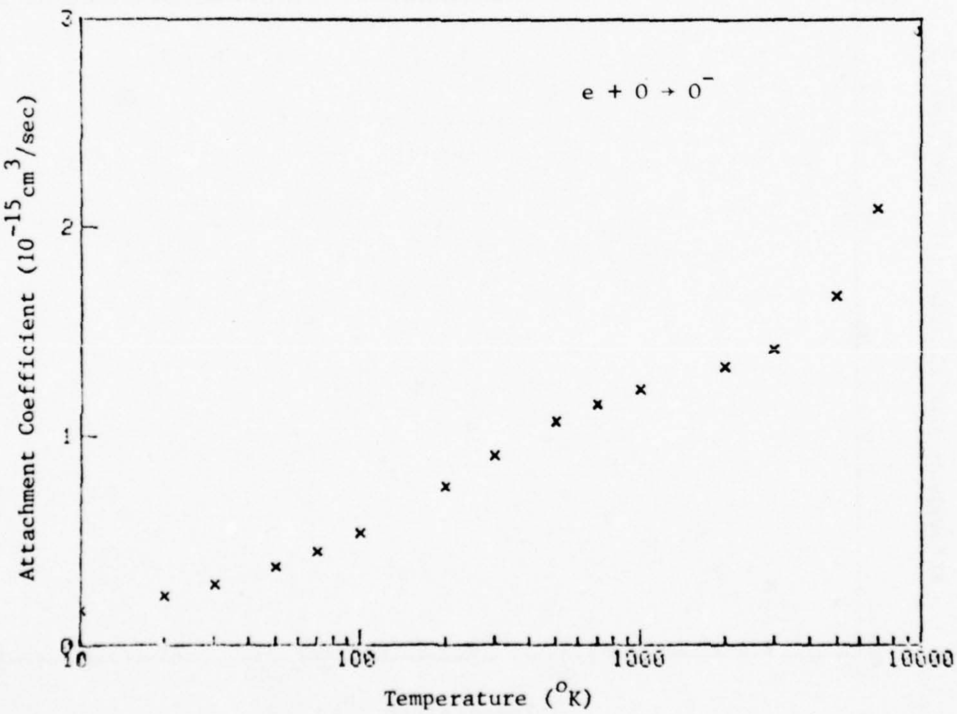
Reference: H. P. Mital, S. Chandra, and U. Narain, J. Phys. Soc. Jpn. 42, 1282 (1977)

Tabular and Graphical Data C-6.3. Coefficient for radiative attachment of electrons to O.

$e + O \rightarrow O^-$

Temperature deg K	Attachment Coefficient $10^{-15}cm^3/sec$	Temperature deg K	Attachment Coefficient $10^{-15}cm^3/sec$
10	0.1650	500	1.071
20	0.2350	700	1.155
30	0.2880	1000	1.226
50	0.3730	2000	1.336
70	0.4440	3000	1.418
100	0.5340	5000	1.675
200	0.7600	7000	2.097
300	0.9070	10000	2.945

Cont. Next Column



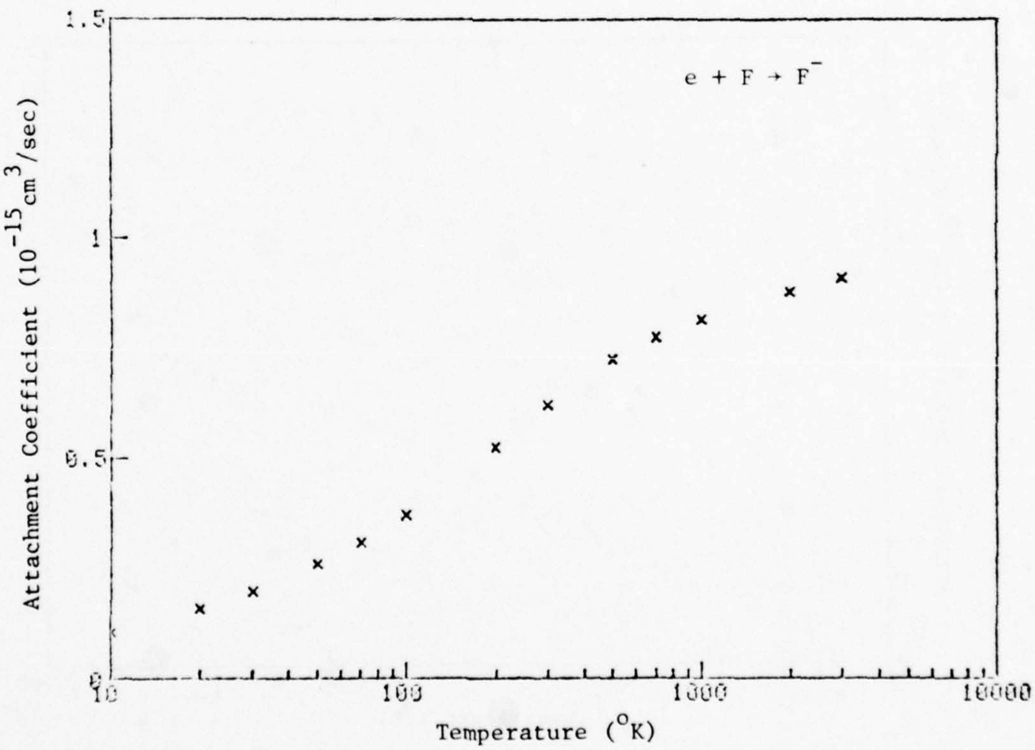
Reference: H. P. Mital, S. Chandra, and U. Narain, J. Phys. Soc. Jpn. 42, 1282 (1977)

Tabular and Graphical Data C-6.4. Coefficient for radiative attachment of electrons to F.

$$e + F \rightarrow F^-$$

Temperature deg K	Attachment Coefficient $10^{-15}cm^3/sec$	Temperature deg K	Attachment Coefficient $10^{-15}cm^3/sec$
10	0.105	300	0.620
20	0.158	500	0.722
30	0.197	700	0.772
50	0.258	1000	0.813
70	0.307	2000	0.877
100	0.370	3000	0.909
200	0.523		

Cont. Next Column



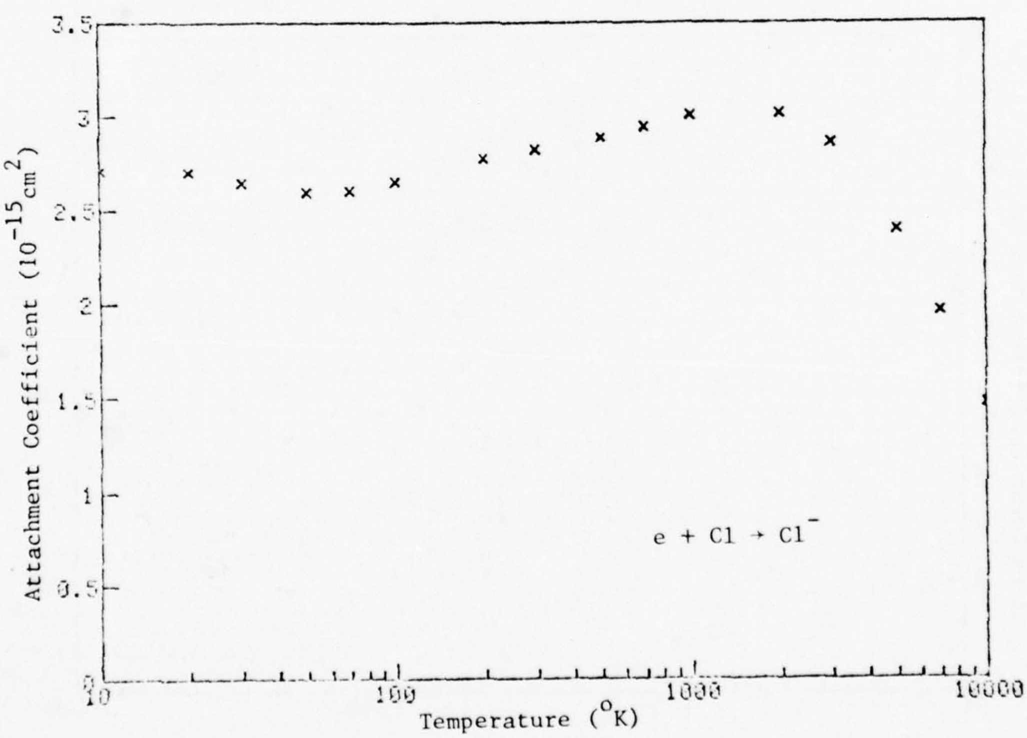
Reference: H. P. Mital, S. Chandra, and U. Narain, J. Phys. Soc. Jpn. 42, 1282 (1977)

Tabular and Graphical Data C-6.5. Coefficient for radiative attachment of electrons to Cl.

$$e + Cl \rightarrow Cl^-$$

Temperature deg K	Attachment Coefficient $10^{-15} cm^3/sec$	Temperature deg K	Attachment Coefficient $10^{-15} cm^3/sec$
10	2.709	500	2.888
20	2.704	700	2.946
30	2.643	1000	3.006
50	2.593	2000	3.013
70	2.601	3000	2.858
100	2.648	5000	2.391
200	2.771	7000	1.953
300	2.822	10000	1.468

Cont. Next Column



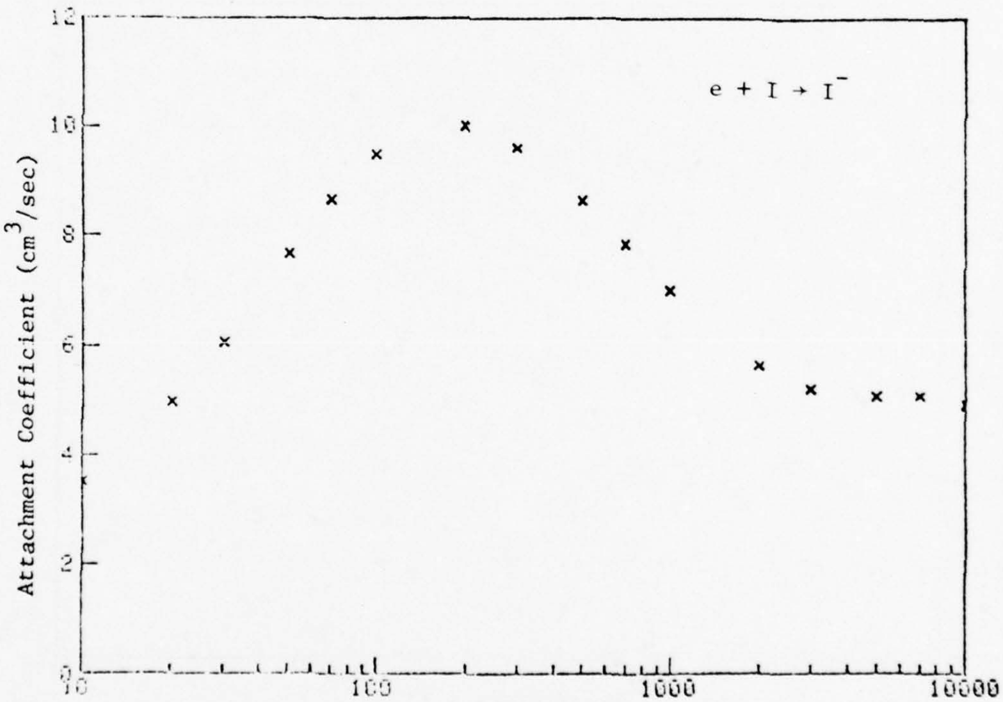
Reference: H. P. Mital, S. Chandra, and U. Narain, J. Phys. Soc. Jpn. 42, 1282 (1977)

Tabular and Graphical Data C-6.6. Coefficient for radiative attachment of electrons to I.

$$e + I \rightarrow I^-$$

Temperature deg K	Attachment Coefficient $10^{-15} cm^3/sec$	Temperature deg K	Attachment Coefficient $10^{-15} cm^3/sec$
10	3.513	500	8.654
20	4.970	700	7.860
30	6.077	1000	7.004
50	7.675	2000	5.643
70	8.681	3000	5.204
100	9.511	5000	5.069
200	10.02	7000	5.081
300	9.631	10000	4.913

Cont. Next Column

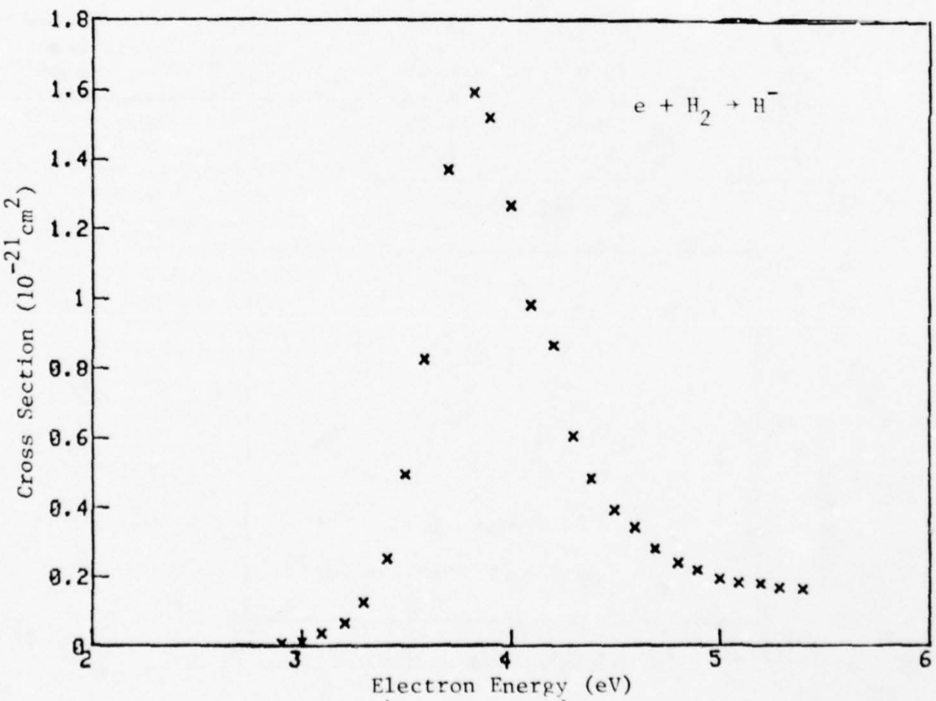


Reference: H. P. Mital, S. Chandra, and U. Narain, J. Phys. Soc. Jpn. 42, 1282 (1977)

Tabular and Graphical Data C-6.7a. Cross sections for dissociative attachment of electrons to H_2.

$$e + H_2 \rightarrow H^-$$

Electron Energy eV	Cross Section $10^{-21}cm^2$	Electron Energy eV	Cross Section $10^{-21}cm^2$	Electron Energy eV	Cross Section $10^{-21}cm^2$
2.90	0.00508	3.82	1.59	4.69	0.278
3.00	0.00877	3.90	1.52	4.80	0.237
3.10	0.0350	4.00	1.27	4.89	0.215
3.20	0.0652	4.10	0.983	5.00	0.190
3.30	0.124	4.20	0.865	5.09	0.179
3.41	0.251	4.30	0.604	5.19	0.178
3.50	0.495	4.39	0.482	5.28	0.165
3.59	0.827	4.49	0.392	5.39	0.162
3.70	1.37	4.59	0.340		
Cont. Next Column		Cont. Next Column			



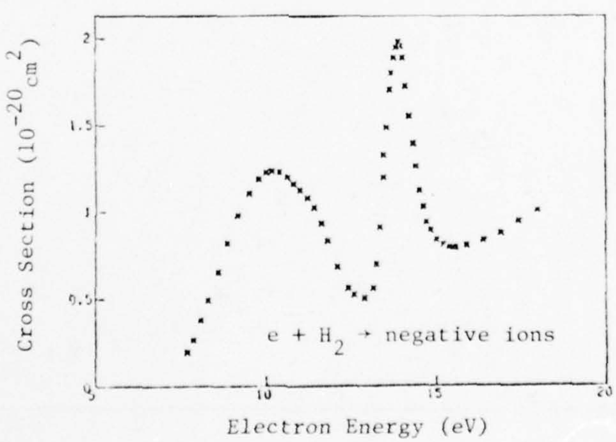
Reference: G. J. Schulz and R. K. Asundi, Phys. Rev. 158, 25 (1967)

Tabular and Graphical Data C-6.7b. Cross sections for dissociative attachment of electrons to H_2.

$e + H_2 \rightarrow$ negative ions

Electron Energy eV	Cross Section $10^{-20}cm^2$	Electron Energy eV	Cross Section $10^{-20}cm^2$	Electron Energy eV	Cross Section $10^{-20}cm^2$
7.67	0.194	12.1	0.680	14.3	1.39
7.84	0.264	12.4	0.557	14.4	1.26
8.08	0.376	12.6	0.517	14.5	1.12
8.30	0.490	12.9	0.501	14.6	1.02
8.59	0.651	13.2	0.556	14.7	0.933
8.87	0.815	13.2	0.692	14.8	0.888
9.17	0.974	13.3	0.903	15.0	0.831
9.48	1.10	13.5	1.19	15.2	0.803
9.78	1.19	13.5	1.32	15.4	0.789
9.99	1.22	13.5	1.48	15.5	0.785
10.2	1.23	13.7	1.70	15.6	0.786
10.4	1.23	13.7	1.80	15.9	0.797
10.6	1.20	13.8	1.89	16.4	0.829
10.8	1.16	13.8	1.95	16.9	0.870
11.0	1.12	13.9	1.98	17.4	0.941
11.2	1.08	13.9	1.95	18.0	1.00
11.4	1.02	14.0	1.89		
11.6	0.929	14.1	1.72		
11.8	0.827	14.2	1.55		

Cont. Next Column Cont. Next Column



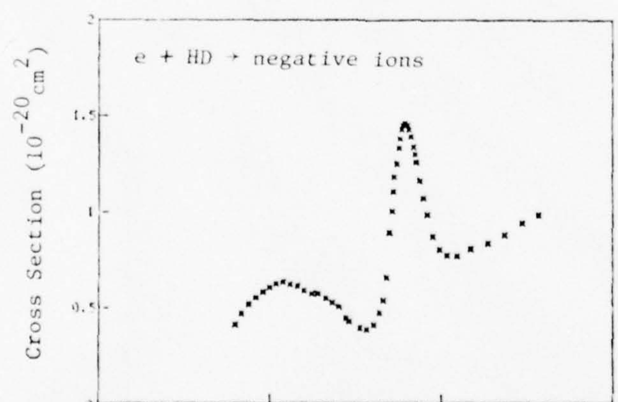
Reference: D. Rapp, T. E. Sharp and D. D. Briglia, Phys. Rev. Letters 14, 533 (1965)

Tabular and Graphical Data C-6.8. Cross sections for dissociative attachment of electrons to HD.

e + HD → negative ions

Electron Energy eV	Cross Section $10^{-20}cm^2$	Electron Energy eV	Cross Section $10^{-20}cm^2$	Electron Energy eV	Cross Section $10^{-20}cm^2$
8.96	0.411	12.6	0.394	14.1	1.39
9.15	0.469	12.8	0.387	14.2	1.34
9.37	0.514	13.0	0.410	14.2	1.30
9.56	0.552	13.2	0.474	14.2	1.26
9.78	0.583	13.3	0.538	14.4	1.16
9.98	0.606	13.4	0.656	14.5	1.07
10.2	0.624	13.5	0.893	14.6	0.984
10.4	0.634	13.5	1.00	14.7	0.870
10.6	0.622	13.6	1.11	14.9	0.804
10.8	0.611	13.6	1.18	15.2	0.773
11.0	0.588	13.7	1.25	15.5	0.769
11.2	0.575	13.7	1.33	15.9	0.803
11.4	0.573	13.8	1.38	16.4	0.836
11.6	0.549	13.8	1.43	16.8	0.878
11.8	0.526	13.9	1.45	17.4	0.938
12.0	0.504	13.9	1.46	17.8	0.983
12.2	0.447	14.0	1.45		
12.3	0.428	14.0	1.43		

Cont. Next Column　　Cont. Next Column



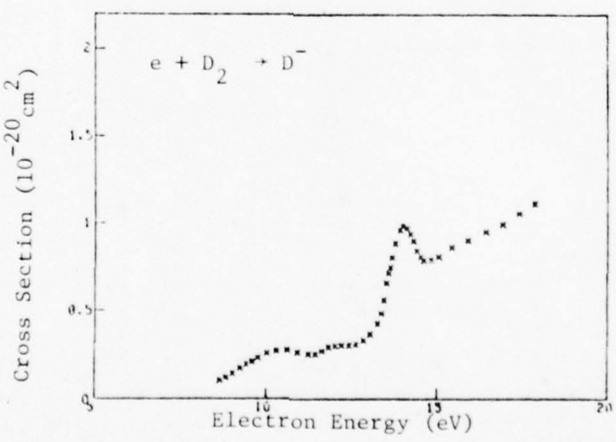
Reference: D. Rapp, T. E. Sharp and D. D. Briglia, Phys. Rev. Letters 14, 533 (1965)

Tabular and Graphical Data C-6.9. Cross sections for dissociative attachment of electrons to D_2.

$$e + D_2 \rightarrow D^-$$

Electron Energy eV	Cross Section $10^{-20}cm^2$	Electron Energy eV	Cross Section $10^{-20}cm^2$	Electron Energy eV	Cross Section $10^{-20}cm^2$
8.65	0.103	12.2	0.304	14.2	0.937
8.83	0.118	12.4	0.303	14.3	0.898
9.02	0.140	12.6	0.310	14.4	0.844
9.24	0.173	12.8	0.330	14.5	0.805
9.43	0.195	13.0	0.366	14.6	0.786
9.59	0.208	13.2	0.427	14.8	0.787
9.76	0.229	13.4	0.485	15.0	0.804
10.0	0.257	13.4	0.560	15.4	0.859
10.3	0.270	13.5	0.659	15.9	0.901
10.6	0.273	13.6	0.713	16.4	0.948
10.9	0.265	13.6	0.748	16.9	0.992
11.2	0.254	13.7	0.804	17.4	1.05
11.4	0.252	13.8	0.885	17.9	1.11
11.6	0.270	13.9	0.963		
11.8	0.292	14.0	0.988		
12.0	0.301	14.1	0.971		

Cont. Next Column
Cont. Next Column



Reference: D. Rapp, T. E. Sharp and D. D. Briglia, Phys. Rev. Letters 14, 533 (1965)

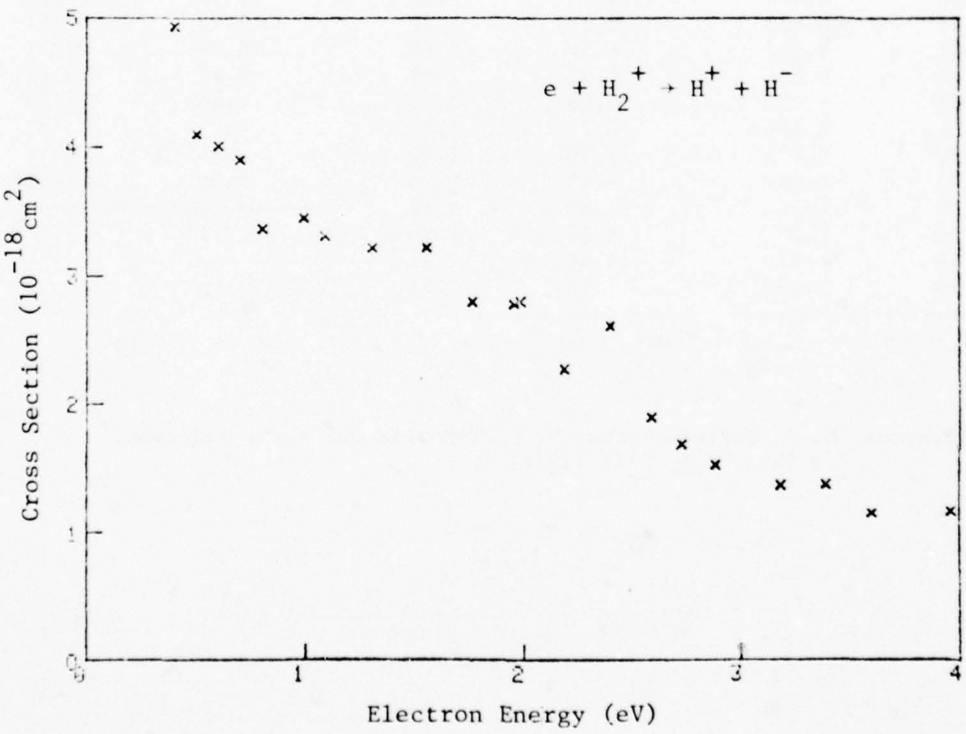
Tabular and Graphical Data C-6.10. Cross sections for dissociative attachment of electrons to H_2^+.

$$e + H_2^+ \rightarrow H^+ + H^-$$

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
0.400	4.94	1.56	3.22	2.88	1.52
0.500	4.10	1.77	2.79	3.18	1.36
0.600	4.01	1.96	2.78	3.39	1.37
0.700	3.90	1.99	2.80	3.60	1.15
0.800	3.37	2.19	2.27	3.96	1.16
0.990	3.46	2.40	2.61		
1.09	3.31	2.59	1.89		
1.31	3.22	2.73	1.68		

Cont. Next Column

Cont. Next Column



Reference: B. Peart and K. T. Dolder, J. Phys. B 8, 1570 (1975)

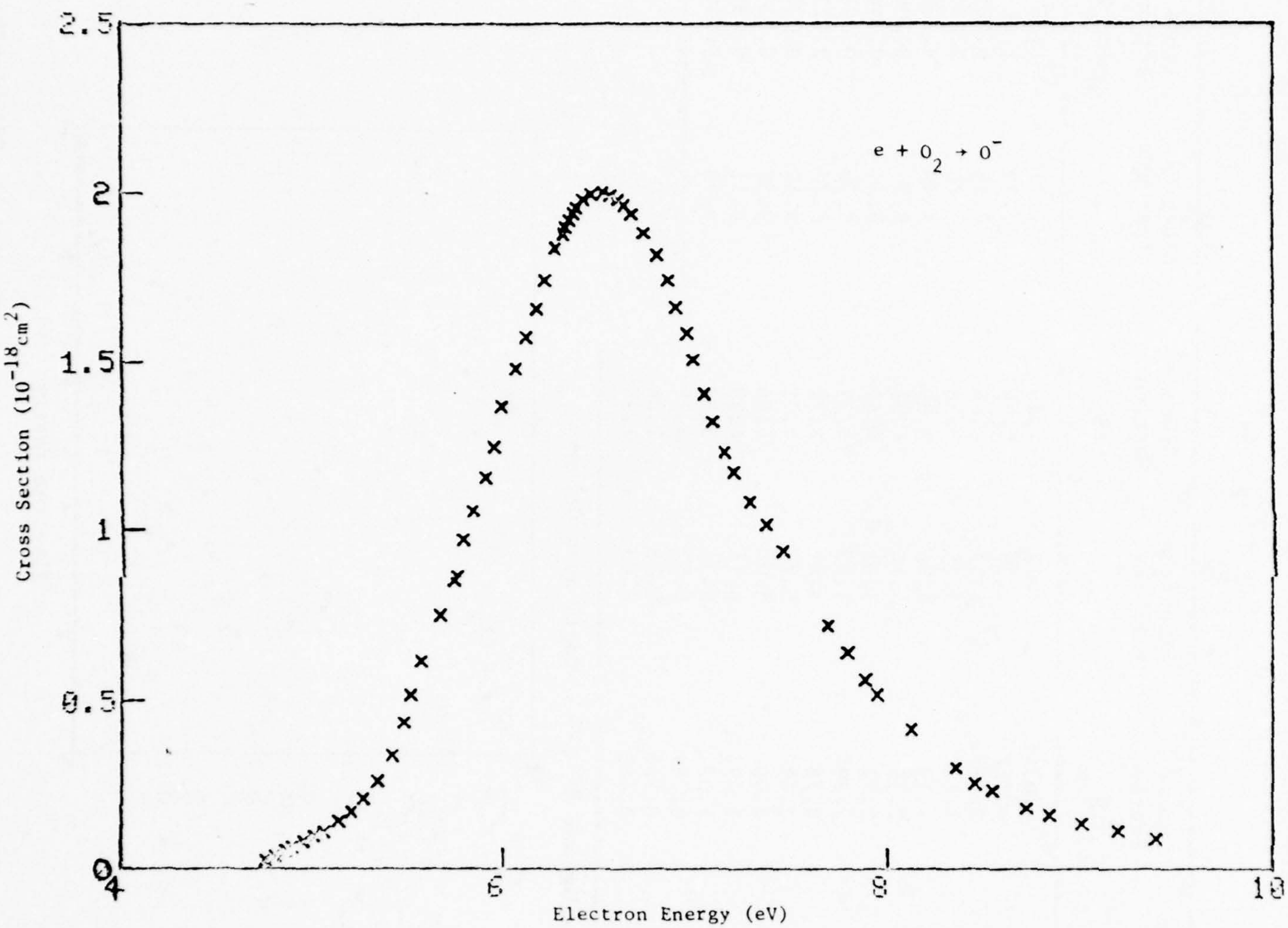
Tabular Data C-6.11. Cross sections for dissociative attachment of electrons to O_2.

$$e + O_2 \rightarrow O^-$$

Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$	Electron Energy eV	Cross Section $10^{-18} cm^2$
4.75	0.0259	6.11	1.57	7.09	1.32
4.80	0.0356	6.17	1.66	7.15	1.23
4.86	0.0518	6.21	1.74	7.20	1.17
4.89	0.0647	6.27	1.84	7.28	1.08
4.95	0.0813	6.31	1.88	7.36	1.01
5.00	0.0955	6.32	1.90	7.44	0.933
5.05	0.110	6.34	1.92	7.69	0.721
5.13	0.140	6.36	1.94	7.79	0.639
5.20	0.168	6.37	1.96	7.88	0.561
5.27	0.208	6.41	1.98	7.94	0.515
5.34	0.261	6.45	2.00	8.12	0.414
5.42	0.337	6.51	2.00	8.35	0.299
5.48	0.435	6.55	1.99	8.45	0.251
5.52	0.517	6.59	1.98	8.54	0.233
5.57	0.616	6.62	1.96	8.72	0.179
5.67	0.751	6.66	1.94	8.84	0.160
5.74	0.854	6.72	1.88	9.01	0.133
5.78	0.970	6.79	1.82	9.20	0.111
5.83	1.06	6.85	1.74	9.39	0.0888
5.90	1.16	6.89	1.66		
5.95	1.25	6.94	1.58		
5.99	1.37	6.98	1.51		
6.06	1.48	7.04	1.41		

Cont. Next Column Cont. Next Column

Reference: L. G. Christophorou, D. L. McCorkle and V. E. Anderson, J. Phys. B 4, 1163 (1971)



Graphical Data C-6.11. Cross sections for dissociative attachment of electrons to O_2.

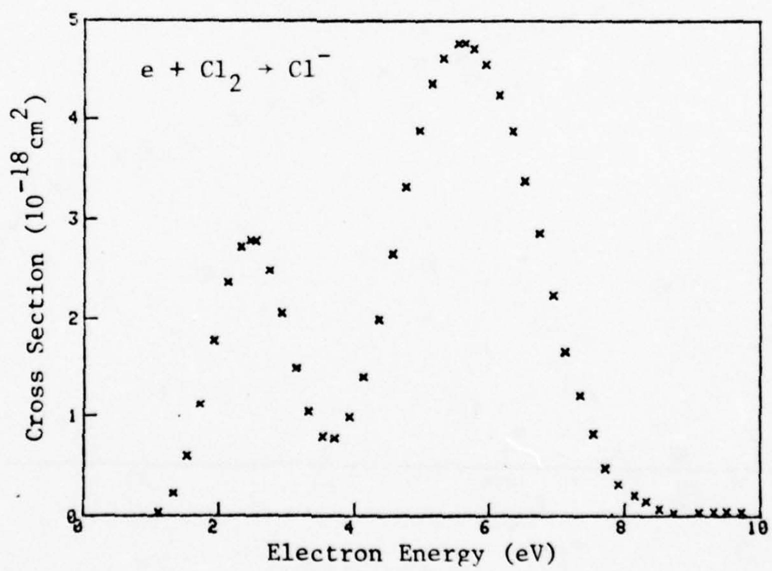
Tabular and Graphical Data C-6.12. Cross sections for dissociative attachment of electrons to Cl_2.

$$e + Cl_2 \rightarrow Cl^-$$

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
1.11	0.0361	4.12	1.40	7.11	1.66
1.32	0.222	4.36	1.99	7.33	1.21
1.53	0.595	4.55	2.66	7.53	0.805
1.72	1.12	4.75	3.33	7.70	0.475
1.92	1.77	4.94	3.89	7.90	0.309
2.14	2.36	5.14	4.36	8.14	0.200
2.33	2.72	5.31	4.62	8.31	0.144
2.46	2.79	5.53	4.77	8.52	0.0618
2.54	2.78	5.63	4.77	8.72	0.0273
2.74	2.49	5.77	4.71	9.10	0.0303
2.92	2.06	5.94	4.56	9.32	0.0396
3.13	1.49	6.14	4.25	9.51	0.0390
3.32	1.03	6.34	3.89	9.73	0.0402
3.52	0.787	6.52	3.39		
3.71	0.765	6.73	2.86		
3.93	0.985	6.93	2.24		

Cont. Next Column

Cont. Next Column

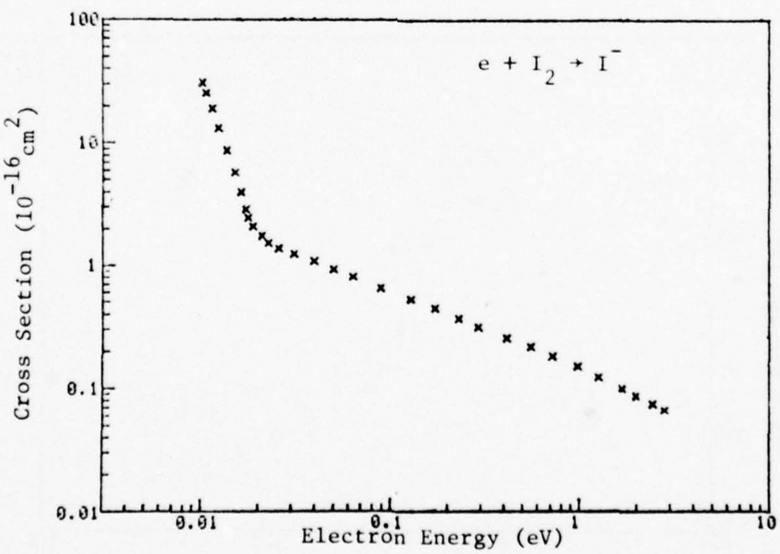


Reference: M. V. Kurepa and D. S. Belic, J. Phys. B 11, 3719 (1978).

Tabular and Graphical Data C-6.13. Cross sections for dissociative attachment of electrons to I_2.

$$e + I_2 \rightarrow I^-$$

Electron Energy (eV)	Cross Section ($10^{-16} cm^2$)	Electron Energy (eV)	Cross Section ($10^{-16} cm^2$)	Electron Energy (eV)	Cross Section ($10^{-16} cm^2$)
0.0101	31.0	0.0227	1.53	0.412	0.257
0.0105	25.4	0.0254	1.38	0.551	0.218
0.0113	18.8	0.0309	1.24	0.717	0.183
0.0123	13.1	0.0394	1.09	0.975	0.151
0.0135	8.75	0.0500	0.929	1.26	0.122
0.0149	5.73	0.0631	0.801	1.68	0.0991
0.0161	3.99	0.0884	0.651	1.99	0.0867
0.0172	2.87	0.127	0.530	2.44	0.0739
0.0177	2.45	0.171	0.449	2.81	0.0663
0.0187	2.07	0.228	0.372		
0.0209	1.74	0.289	0.314		
Cont. Next Column		Cont. Next Column			



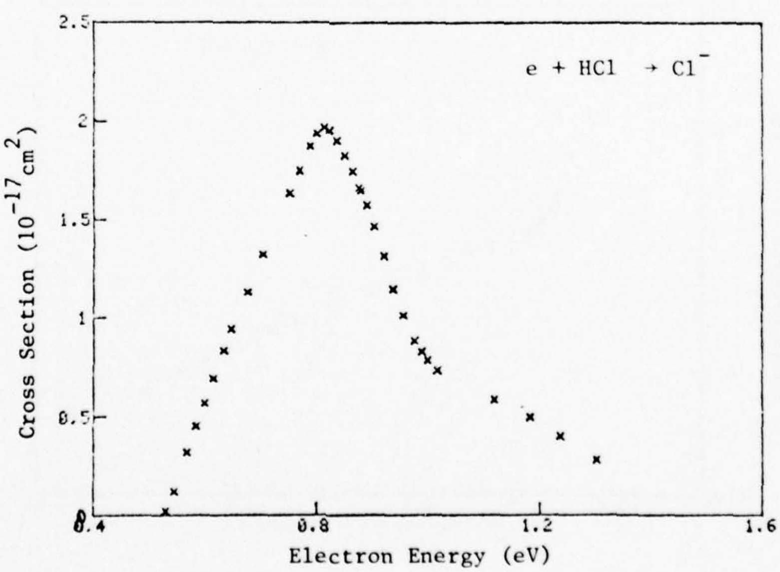
Reference: M. A. Biondi and R. E. Fox, Phys. Rev. 109, 2012 (1958)

Tabular and Graphical Data C-6.14a. Cross sections for dissociative attachment of electrons to HCl.

$e + HCl \rightarrow Cl^-$

Electron Energy ev	Cross Section $10^{-17}cm^2$	Electron Energy ev	Cross Section $10^{-17}cm^2$	Electron Energy ev	Cross Section $10^{-17}cm^2$
0.529	0.0188	0.789	1.87	0.939	1.15
0.544	0.121	0.801	1.94	0.957	1.01
0.566	0.320	0.814	1.97	0.977	0.884
0.583	0.451	0.823	1.96	0.989	0.829
0.598	0.566	0.837	1.91	1.00	0.783
0.613	0.691	0.851	1.83	1.02	0.732
0.631	0.833	0.865	1.75	1.12	0.583
0.646	0.940	0.876	1.67	1.18	0.498
0.675	1.13	0.880	1.65	1.24	0.401
0.703	1.32	0.892	1.58	1.30	0.278
0.752	1.64	0.904	1.47		
0.770	1.75	0.922	1.32		

Cont. Next Column   Cont. Next Column

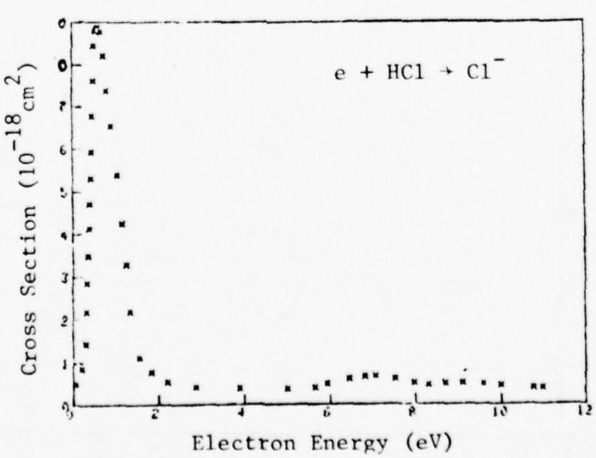


Reference: L. G. Christophorou, R. N. Compton, and H. W. Dickson, J. Chem. Phys. 48, 1949 (1968)

Tabular and Graphical Data C-6.14a. Cross sections for dissociative attachment of electrons to HCl (Concluded).

$e + HCl \rightarrow Cl^-$

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
0.043	0.49	0.60	8.9	5.7	0.39
0.21	0.85	0.66	8.8	5.9	0.48
0.30	1.4	0.73	8.2	6.5	0.59
0.31	2.2	0.80	7.4	6.8	0.65
0.32	2.9	0.90	6.5	7.1	0.66
0.35	3.5	1.0	5.4	7.5	0.58
0.38	4.1	1.1	4.2	8.0	0.49
0.40	4.7	1.2	3.3	8.3	0.45
0.42	5.3	1.3	2.2	8.7	0.47
0.44	5.9	1.5	1.1	9.1	0.49
0.45	6.8	1.8	0.75	9.6	0.47
0.50	7.6	2.2	0.52	10.0	0.44
0.49	8.5	2.9	0.40	11	0.38
0.53	8.8	3.9	0.38	11	0.38
0.54	8.9	5.0	0.36	12	0.30
Cont. Next Column		Cont. Next Column			

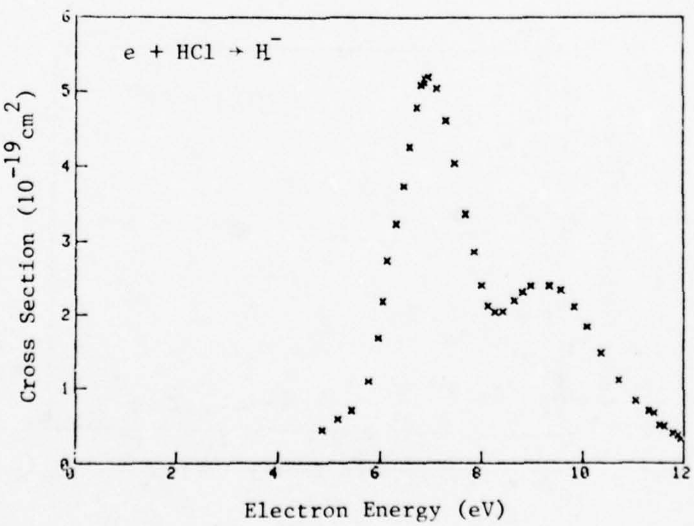


Reference: R. Azria, L. Roussier, R. Paineau, and M. Tronc, Rev. Phys. Appl. 9, 469 (1974)

Tabular and Graphical Data C-6.14b. Cross sections for dissociative attachment of electrons to HCl.

$e + HCl \rightarrow H^-$

Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$
4.9	0.44	7.0	5.2	9.6	2.3
5.2	0.58	7.1	5.1	9.8	2.1
5.4	0.69	7.3	4.6	10	1.8
5.8	1.1	7.5	4.0	10	1.5
6.0	1.7	7.7	3.4	11	1.1
6.1	2.2	7.9	2.8	11	0.83
6.1	2.7	8.0	2.4	11	0.69
6.3	3.2	8.1	2.1	11	0.66
6.5	3.7	8.3	2.0	12	0.50
6.6	4.3	8.4	2.0		
6.7	4.8	8.6	2.2		
6.8	5.1	8.8	2.3		
6.9	5.1	9.0	2.4		
6.9	5.2	9.3	2.4		
Cont. Next Column		Cont. Next Column			



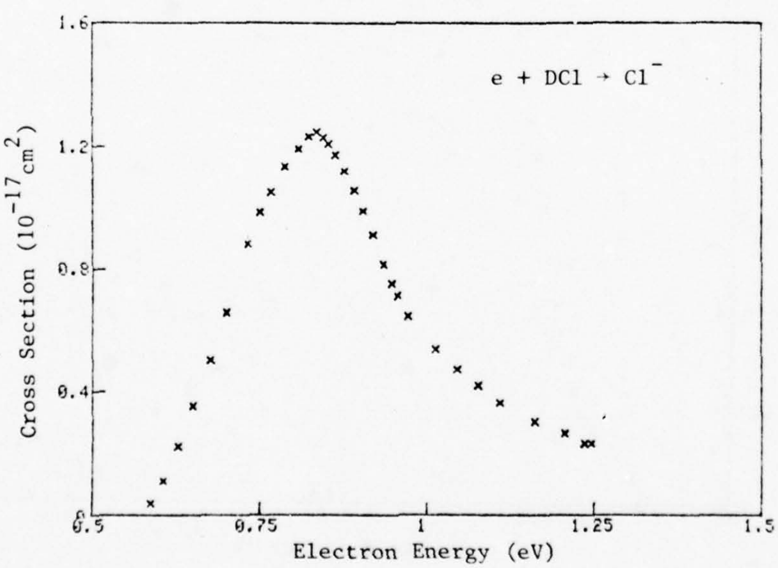
Reference: R. Azria, L. Roussier, R. Paineau and M. Tronc, Rev. Phys. Appl. 9, 469 (1974)

Tabular and Graphical Data C-6.15. Cross sections for dissociative attachment of electrons to DCl.

$e + DCl \rightarrow Cl^-$

Electron Energy eV	Cross Section $10^{-17}cm^2$	Electron Energy eV	Cross Section $10^{-17}cm^2$	Electron Energy eV	Cross Section $10^{-17}cm^2$
0.587	0.0376	0.836	1.25	1.01	0.537
0.605	0.111	0.846	1.23	1.05	0.470
0.627	0.224	0.854	1.21	1.08	0.418
0.650	0.354	0.864	1.18	1.11	0.362
0.676	0.501	0.877	1.12	1.16	0.303
0.700	0.654	0.893	1.06	1.21	0.263
0.732	0.880	0.905	0.990	1.23	0.232
0.750	0.987	0.920	0.911	1.25	0.232
0.767	1.05	0.936	0.815		
0.788	1.14	0.948	0.749		
0.809	1.19	0.957	0.710		
0.825	1.23	0.972	0.643		

Cont. Next Column   Cont. Next Column



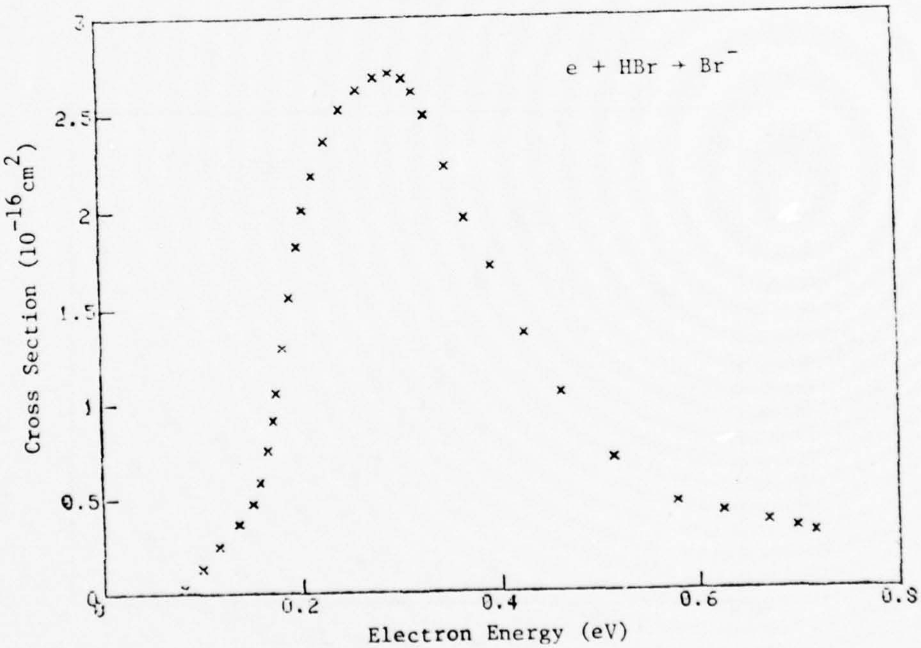
Reference: L. G. Christophorou, R. N. Compton, and H. W. Dickson, J. Chem. Phys. 48, 1949 (1968)

Tabular and Graphical Data C-6.16. Cross sections for dissociative attachment of electrons to HBr.

$$e + HBr \rightarrow Br^-$$

Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$	Electron Energy eV	Cross Section $10^{-16} cm^2$
0.0791	0.0241	0.197	1.82	0.348	2.23
0.0976	0.129	0.204	2.01	0.367	1.96
0.114	0.246	0.215	2.19	0.393	1.71
0.135	0.363	0.227	2.36	0.427	1.36
0.150	0.468	0.244	2.53	0.464	1.04
0.158	0.579	0.261	2.63	0.515	0.698
0.166	0.749	0.278	2.69	0.578	0.459
0.172	0.909	0.293	2.71	0.624	0.408
0.175	1.05	0.306	2.68	0.668	0.355
0.181	1.29	0.316	2.61	0.696	0.324
0.189	1.55	0.326	2.49	0.715	0.297

Cont. Next Column　　Cont. Next Column



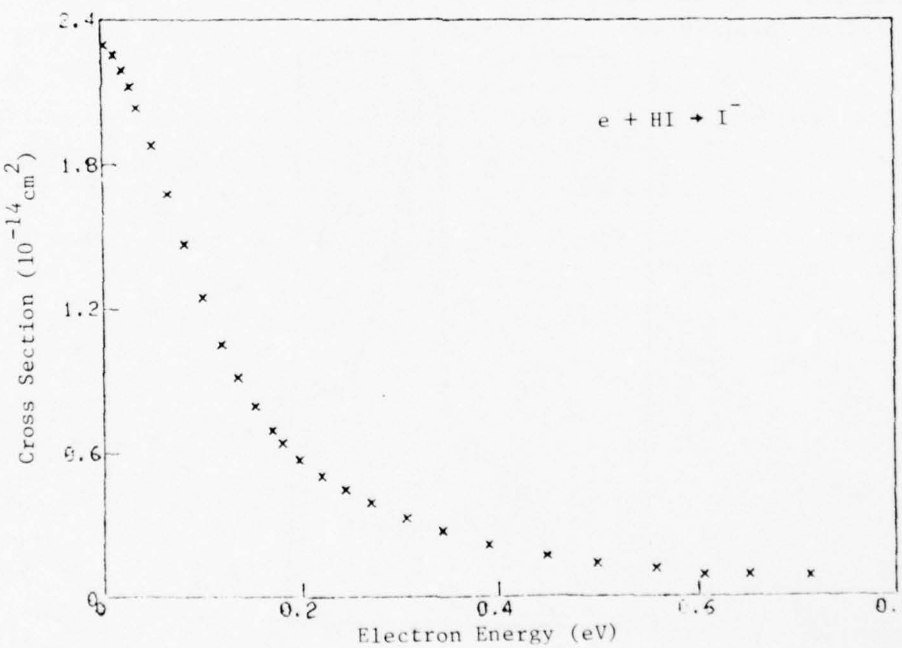
Reference. L. G. Christophorou, R. N. Compton, and H. W. Dickson J. Chem. Phys. 48, 1949 (1968)

Tabular and Graphical Data C-6.17. Cross sections for dissociative attachment of electrons to HI.

$e + HI \rightarrow I^-$

Electron Energy eV	Cross Section $10^{-14}cm^2$	Electron Energy eV	Cross Section $10^{-14}cm^2$	Electron Energy eV	Cross Section $10^{-14}cm^2$
0.0017	2.30	0.12	1.05	0.31	0.328
0.012	2.25	0.14	0.910	0.34	0.274
0.020	2.19	0.15	0.792	0.39	0.215
0.028	2.12	0.17	0.692	0.45	0.167
0.035	2.03	0.18	0.636	0.50	0.138
0.049	1.88	0.20	0.567	0.56	0.115
0.065	1.68	0.22	0.505	0.61	0.0893
0.083	1.47	0.24	0.447	0.65	0.0873
0.10	1.24	0.27	0.391	0.71	0.0797

Cont. Next Column   Cont. Next Column



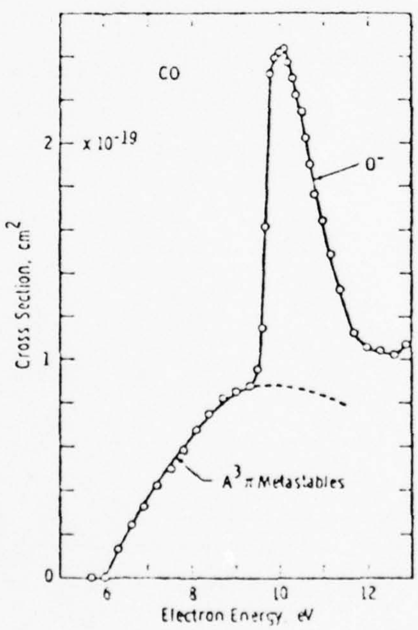
Reference: L. G. Christophorou, R. N. Compton, and H. W. Dickson, J. Chem. Phys. 48, 1949 (1968)

Tabular and Graphical Data C-6.18a. Cross sections for dissociative attachment of electrons to CO.

$$e + CO \rightarrow O^-$$

Electron Energy eV	Cross Section $10^{-19}cm^2$	Electron Energy eV	Cross Section $10^{-19}cm^2$
9.53	0.957	10.7	1.91
9.65	1.15	10.8	1.77
9.72	1.62	11.0	1.65
9.85	2.31	11.2	1.49
9.95	2.39	11.4	1.33
10.1	2.42	11.7	1.12
10.2	2.43	12.0	1.05
10.3	2.37	12.3	1.04
10.4	2.29	12.6	1.02
10.4	2.22	12.9	1.07
10.5	2.14		
10.7	2.02		

Cont. Next Column

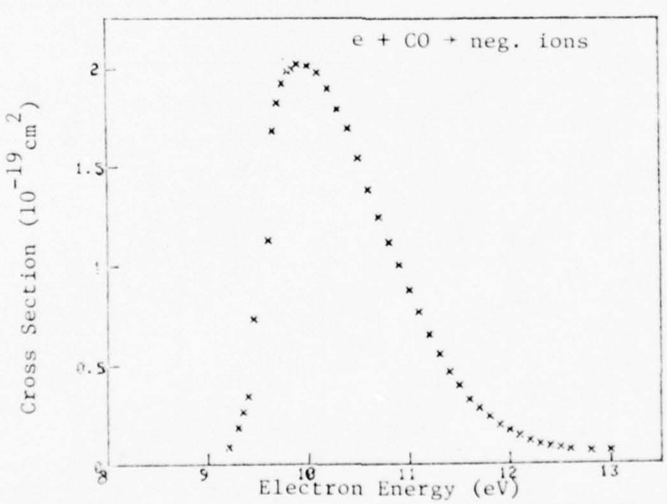


Reference: G. J. Schulz, Phys. Rev. 128, 178 (1962)

Tabular and Graphical Data C-6.18b. Cross sections for dissociative attachment of electrons to CO.

e + CO → negative ions

Electron Energy eV	Cross Section $10^{-19}cm^2$	Electron Energy eV	Cross Section $10^{-19}cm^2$	Electron Energy eV	Cross Section $10^{-19}cm^2$
9.20	0.0880	10.2	1.90	11.6	0.326
9.30	0.185	10.3	1.80	11.7	0.282
9.35	0.264	10.4	1.70	11.8	0.238
9.40	0.343	10.5	1.55	11.9	0.194
9.45	0.730	10.6	1.38	12.0	0.167
9.60	1.13	10.7	1.24	12.1	0.141
9.65	1.69	10.8	1.12	12.2	0.114
9.70	1.83	10.9	1.00	12.3	0.0968
9.75	1.93	11.0	0.880	12.4	0.0880
9.80	1.99	11.1	0.766	12.5	0.0792
9.85	2.00	11.2	0.651	12.6	0.0704
9.90	2.02	11.3	0.554	12.8	0.0616
10.00	2.02	11.4	0.466	13.0	0.0616
10.1	1.98	11.5	0.396		
Cont. Next Column		Cont. Next Column			

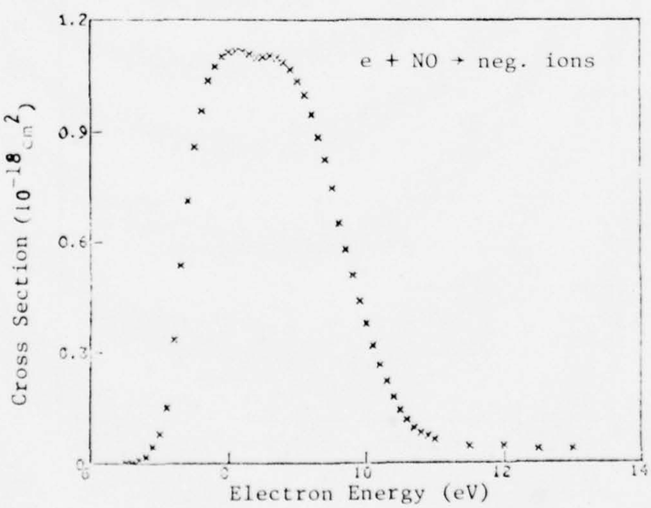


Reference: D. Rapp and D. D. Briglia, J. Chem. Phys. 43, 1480 (1965)

Tabular and Graphical Data C-6.19. Cross sections for dissociative attachment of electrons to NO.

e + NO → negative ions

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
6.50	0	8.10	1.12	9.70	0.581
6.60	0	8.20	1.12	9.80	0.510
6.70	0.00880	8.30	1.11	9.90	0.440
6.80	0.0176	8.40	1.10	10.00	0.378
6.90	0.0440	8.50	1.10	10.1	0.317
7.00	0.0792	8.60	1.11	10.2	0.264
7.10	0.150	8.70	1.10	10.3	0.220
7.20	0.334	8.80	1.09	10.4	0.176
7.30	0.537	8.90	1.07	10.5	0.141
7.40	0.713	9.00	1.04	10.6	0.114
7.50	0.862	9.10	1.00	10.7	0.0924
7.60	0.959	9.20	0.950	10.8	0.0792
7.70	1.04	9.30	0.889	10.9	0.0704
7.80	1.08	9.40	0.827	11.0	0.0616
7.90	1.10	9.50	0.748	11.5	0.0440
8.00	1.11	9.60	0.651	12.0	0.0440
				12.5	0.0352
Cont. Next Column		Cont. Next Column		13.0	0.0352



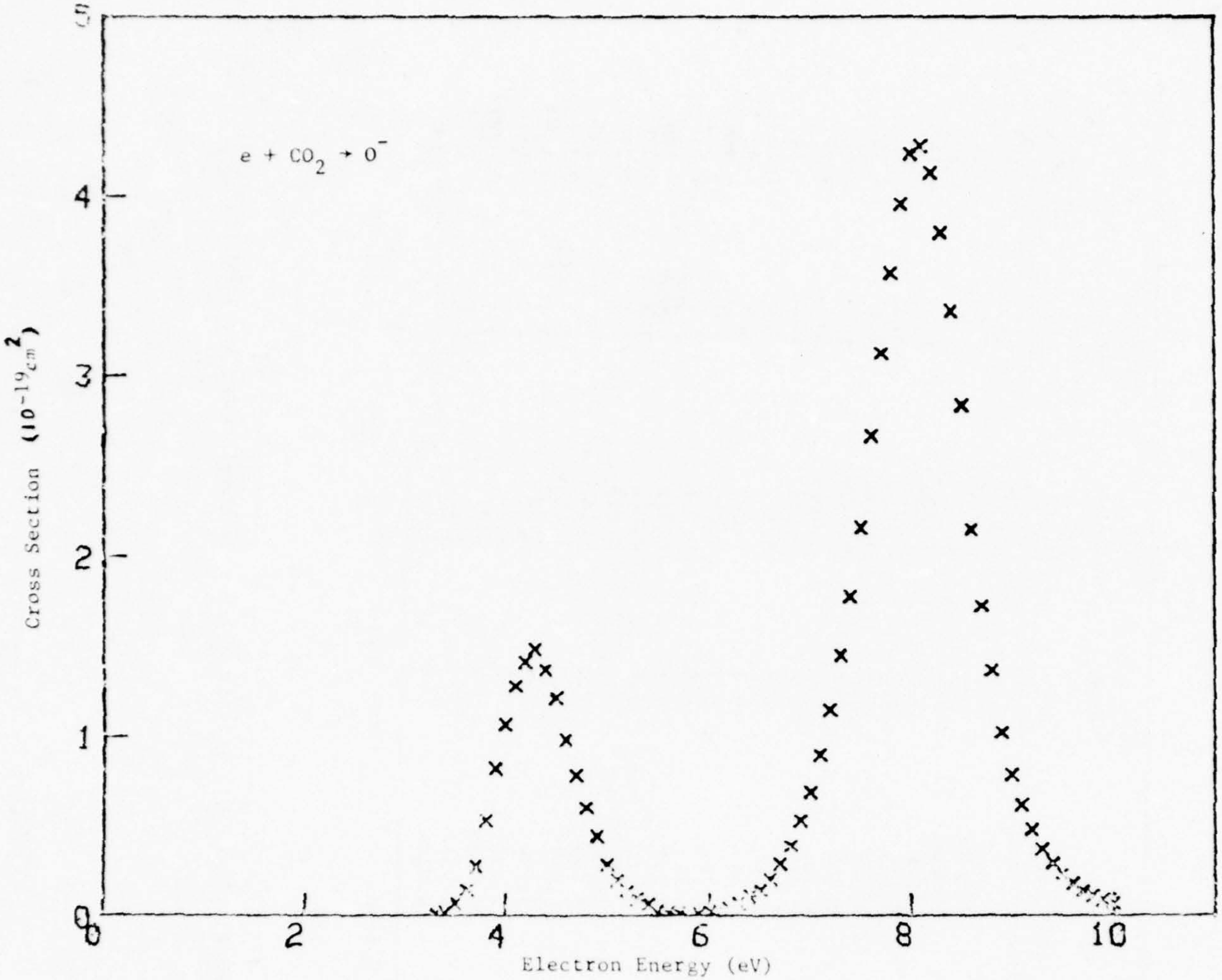
Reference: Rapp, D., Briglia, D. D., J. Chem. Phys. 43, 1480 (1965)

Tabular Data C-6.20a. Cross sections for dissociative attachment of electrons to CO_2 to form O^-.

$$e + CO_2 \rightarrow O^-$$

Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$
3.3	0	5.6	0.0176	7.9	3.96
3.4	0.0176	5.7	0.00880	8.0	4.24
3.5	0.0616	5.8	0	8.1	4.29
3.6	0.141	5.9	0.00880	8.2	4.14
3.7	0.273	6.0	0.0176	8.3	3.80
3.8	0.528	6.1	0.0264	8.4	3.36
3.9	0.818	6.2	0.0440	8.5	2.83
4.0	1.06	6.3	0.0616	8.6	2.15
4.1	1.28	6.4	0.106	8.7	1.72
4.2	1.41	6.5	0.141	8.8	1.36
4.3	1.48	6.6	0.202	8.9	1.02
4.4	1.36	6.7	0.290	9.0	0.783
4.5	1.21	6.8	0.387	9.1	0.616
4.6	0.977	6.9	0.528	9.2	0.484
4.7	0.774	7.0	0.686	9.3	0.370
4.8	0.598	7.1	0.898	9.4	0.290
4.9	0.440	7.2	1.14	9.5	0.229
5.0	0.282	7.3	1.45	9.6	0.176
5.1	0.194	7.4	1.78	9.7	0.132
5.2	0.132	7.5	2.16	9.8	0.106
5.3	0.0880	7.6	2.67	9.9	0.0792
5.4	0.0616	7.7	3.12	10.0	0.0616
5.5	0.0264	7.8	3.57		
Cont. Next Column		Cont. Next Column			

Reference: Rapp. D., Briglia, D. D., J. Chem. Phys. 43, 1480 (1971)



Graphical Data C-6.20a. Cross sections for dissociative attachment of electrons to CO_2 to form O^-.

Tabular Data C-6.20b. Cross sections for dissociative attachment of electrons to CO_2 to form O^-.

$$e + CO_2 \rightarrow O^-$$

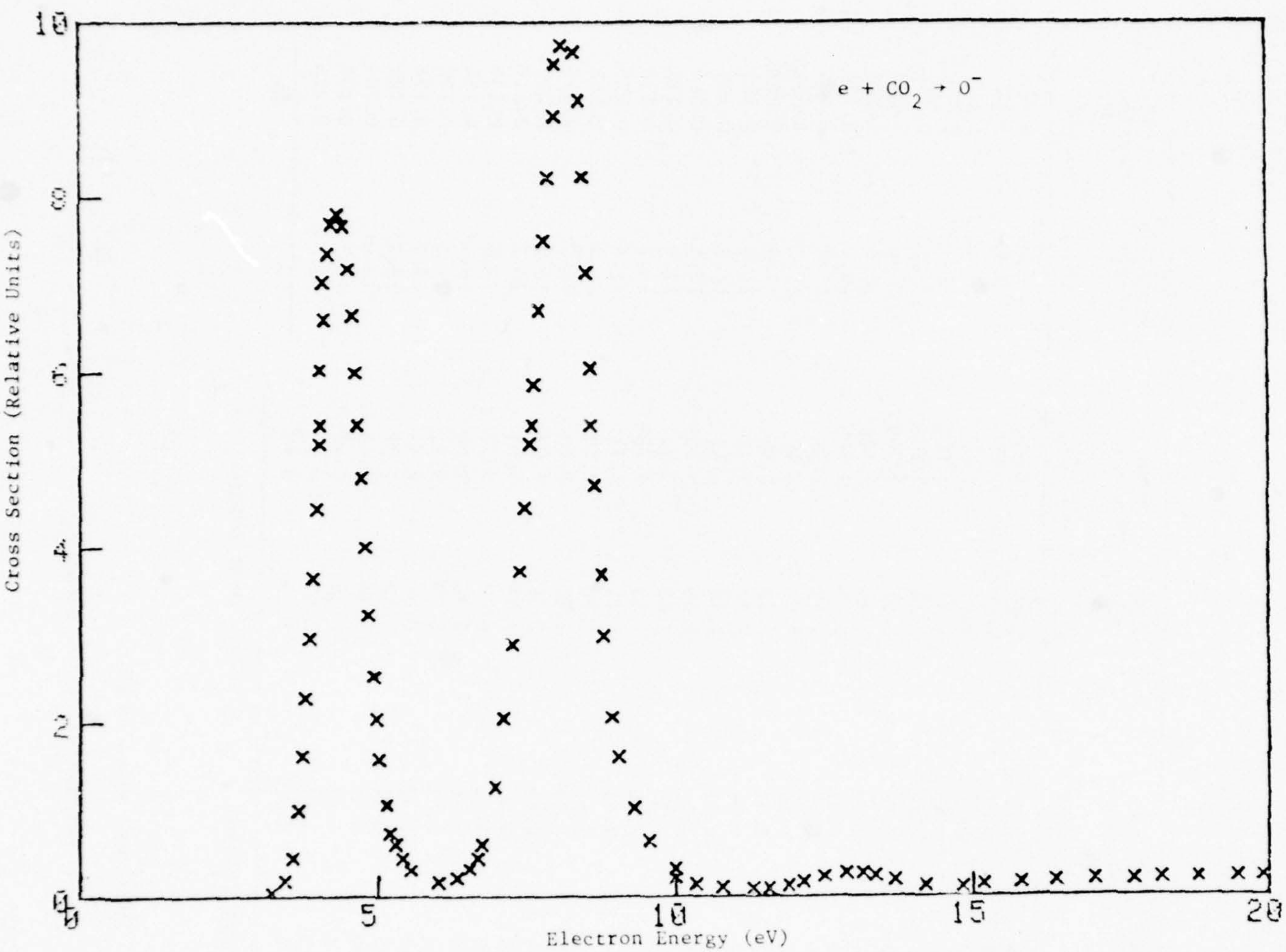
Electron Energy eV	Cross Section unknown	Electron Energy eV	Cross Section unknown	Electron Energy eV	Cross Section unknown
3.20	0.0362	5.27	0.595	8.80	2.98
3.43	0.178	5.41	0.429	8.94	2.04
3.57	0.429	5.55	0.295	9.06	1.58
3.66	0.977	6.01	0.167	9.31	0.998
3.72	1.61	6.30	0.208	9.57	0.621
3.77	2.27	6.52	0.309	10.0	0.305
3.84	2.96	6.66	0.436	10.0	0.204
3.90	3.65	6.73	0.598	10.4	0.136
3.96	4.46	6.95	1.25	10.8	0.104
4.01	5.20	7.10	2.03	11.3	0.0835
4.02	5.41	7.26	2.88	11.6	0.0821
4.02	6.04	7.38	3.72	11.9	0.112
4.08	6.61	7.46	4.45	12.1	0.160
4.08	7.04	7.56	5.19	12.5	0.214
4.15	7.36	7.60	5.40	12.9	0.256
4.22	7.70	7.63	5.86	13.2	0.258
4.34	7.81	7.71	6.71	13.4	0.225
4.41	7.68	7.80	7.50	13.7	0.168
4.49	7.19	7.87	8.23	14.2	0.117
4.55	6.66	7.98	8.93	14.8	0.0996
4.60	6.01	7.99	9.53	15.2	0.127
4.65	5.42	8.09	9.75	15.8	0.139
4.72	4.80	8.31	9.66	16.4	0.160
4.77	4.01	8.39	9.11	17.1	0.170
4.82	3.23	8.45	8.24	17.7	0.174
4.92	2.52	8.52	7.14	18.2	0.186
4.96	2.04	8.58	6.04	18.8	0.205
5.02	1.56	8.59	5.40	19.5	0.208
5.13	1.05	8.65	4.71	19.9	0.218
5.20	0.722	8.76	3.68		

Cont. Next Column

Cont. Next Column

Note peak above 10 eV.

Reference: P. J. Chantry, J. Chem. Phys. 57, 3180 (1972)



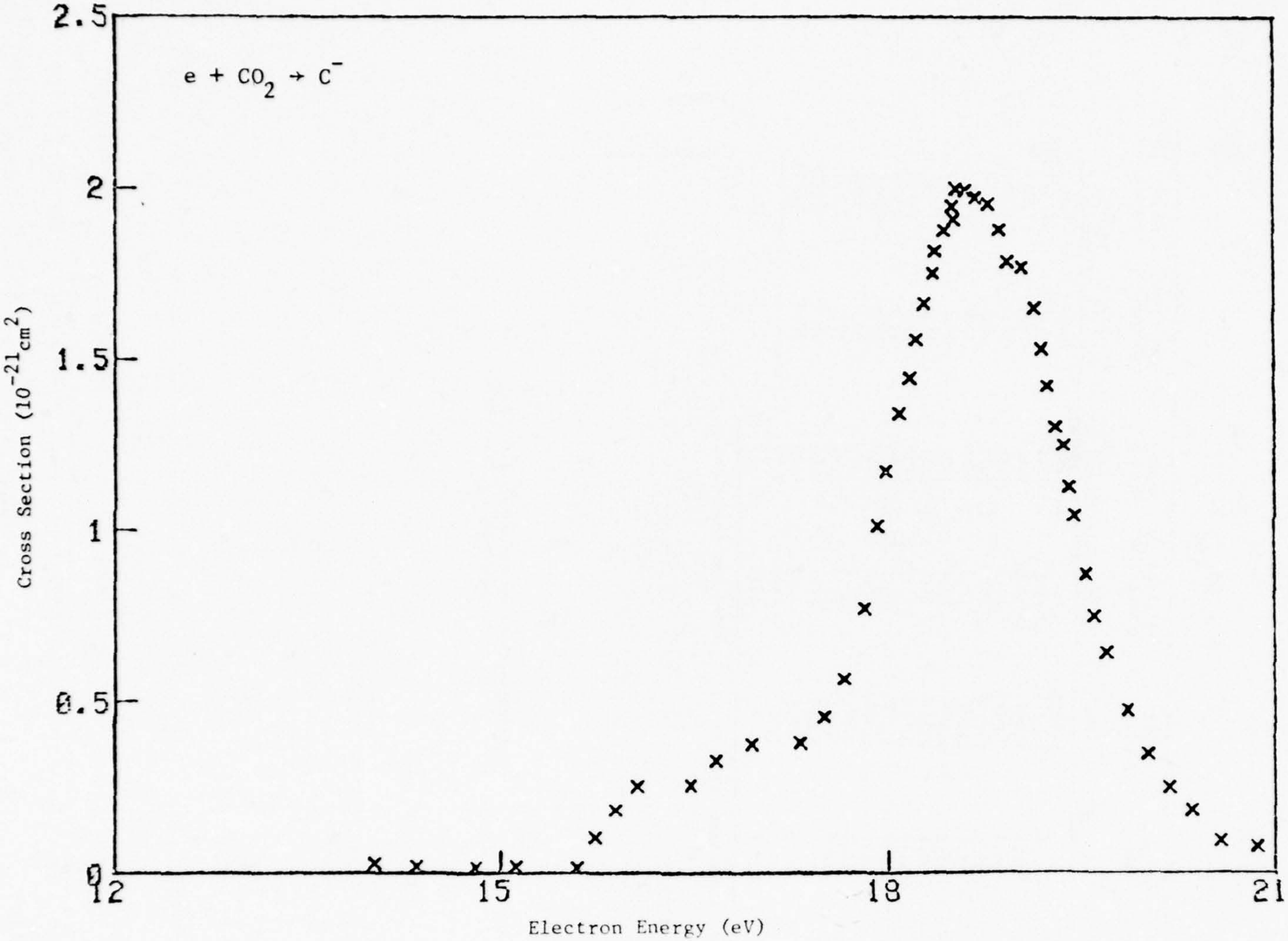
Graphical Data C-6.20b. Cross sections for dissociative attachment of electrons to CO_2 to form O^-.

Tabular Data C-6.21. Cross sections for dissociative attachment of electrons to CO_2.

$$e + CO_2 \rightarrow C^-$$

Electron Energy eV	Cross Section 10^{-21} cm^2	Electron Energy eV	Cross Section 10^{-21} cm^2	Electron Energy eV	Cross Section 10^{-21} cm^2
14.0	0.0251	18.1	1.34	19.2	1.53
14.3	0.0163	18.2	1.44	19.2	1.42
14.8	0.0145	18.2	1.56	19.3	1.30
15.1	0.0173	18.3	1.66	19.4	1.25
15.6	0.0116	18.4	1.75	19.4	1.13
15.7	0.102	18.4	1.82	19.4	1.05
15.9	0.178	18.4	1.88	19.5	0.873
16.0	0.247	18.5	1.91	19.6	0.749
16.5	0.253	18.5	1.95	19.7	0.640
16.7	0.324	18.5	2.00	19.9	0.473
16.9	0.371	18.6	2.00	20.0	0.346
17.3	0.377	18.7	1.98	20.2	0.249
17.5	0.452	18.8	1.96	20.4	0.181
17.7	0.563	18.9	1.88	20.6	0.0919
17.8	0.766	18.9	1.79	20.9	0.0784
17.9	1.01	19.0	1.77		
18.0	1.17	19.1	1.65		
Cont. Next Column		Cont. Next Column			

Reference: D. Spence and G. J. Schulz, J. Chem Phys. 60, 216 (1974)



Graphical Data C-6.21. Cross sections for dissociative attachment of electrons to CO_2 to form C^-.

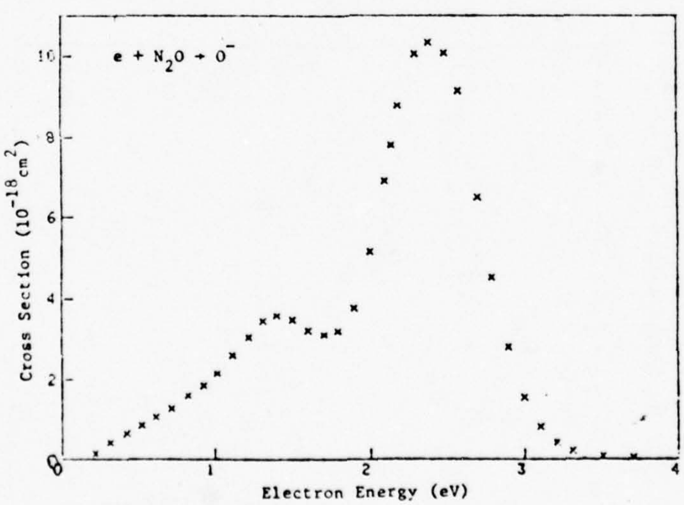
Tabular and Graphical Data C-6.22a. Cross sections for dissociative attachment of electrons to N_2O.

$e + N_2O \rightarrow O^-$

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
0.213	0.165	1.40	3.57	2.49	10.1
0.312	0.431	1.50	3.46	2.58	9.15
0.418	0.629	1.61	3.21	2.70	6.50
0.517	0.847	1.71	3.09	2.79	4.51
0.611	1.06	1.80	3.18	2.90	2.78
0.715	1.27	1.90	3.75	3.00	1.54
0.820	1.59	2.00	5.14	3.10	0.808
0.921	1.83	2.10	6.90	3.21	0.433
1.01	2.14	2.14	7.81	3.31	0.213
1.11	2.58	2.18	8.79	3.51	0.0828
1.22	3.03	2.29	10.1	3.71	0.0534
1.31	3.43	2.39	10.3		

Cont. Next Column

Cont. Next Column

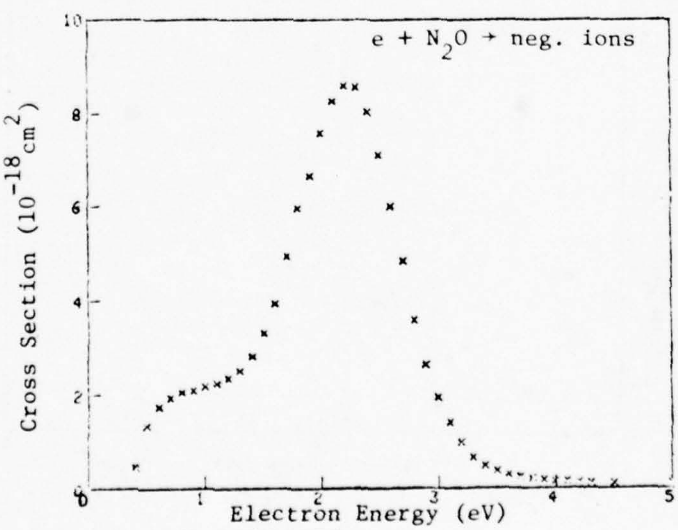


Reference: L. G. Christophorou, D. L. McCorkle, and V. E. Anderson, J. Phys. B 4, 1163 (1971)

Tabular and Graphical Data C-6.22b. Cross sections for dissociative attachment of electrons to N_2O.

$e + N_2O \rightarrow$ negative ions

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
0.40	0.458	1.9	6.64	3.4	0.466
0.50	1.33	2.0	7.59	3.5	0.352
0.60	1.73	2.1	8.28	3.6	0.282
0.70	1.93	2.2	8.61	3.7	0.229
0.80	2.04	2.3	8.57	3.8	0.194
0.90	2.09	2.4	8.04	3.9	0.167
1.0	2.16	2.5	7.10	4.0	0.132
1.1	2.24	2.6	5.98	4.1	0.123
1.2	2.33	2.7	4.84	4.2	0.106
1.3	2.49	2.8	3.57	4.3	0.0968
1.4	2.79	2.9	2.60	4.5	0.0968
1.5	3.29	3.0	1.92	5.0	0.0968
1.6	3.92	3.1	1.39		
1.7	4.94	3.2	0.968		
1.8	5.95	3.3	0.634		
Cont. Next Column		Cont. Next Column			

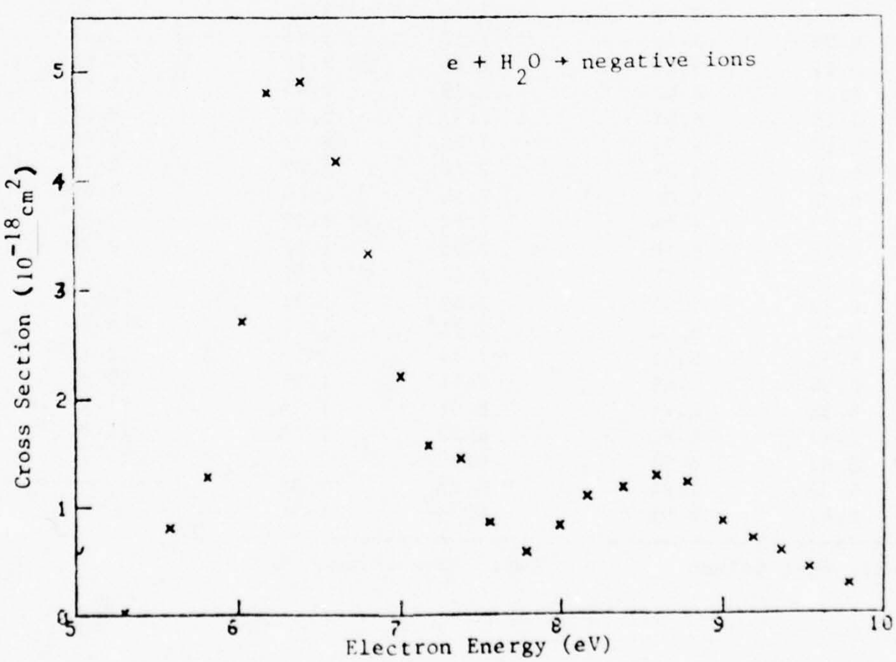


Reference: D. Rapp and D. D. Briglia, J. Chem. Phys. 43, 1480 (1965)

Tabular and Graphical Data C-6.23a. Cross sections for dissociative attachment of electrons to H_2O.

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
5.3	0.0200	7.0	2.21	8.6	1.28
5.6	0.800	7.2	1.57	8.8	1.21
5.8	1.28	7.4	1.44	9.0	0.850
6.0	2.71	7.6	0.850	9.2	0.690
6.2	4.80	7.8	0.570	9.4	0.570
6.4	4.90	8.0	0.820	9.5	0.420
6.6	4.17	8.2	1.09	9.8	0.270
6.8	3.34	8.4	1.17		

Cont. Next Column   Cont. Next Column



Reference: I. S. Buchelnikova, Sov. Phys. JETP USSR (Eng. Trans.) <u>35</u>, 783 (1959)

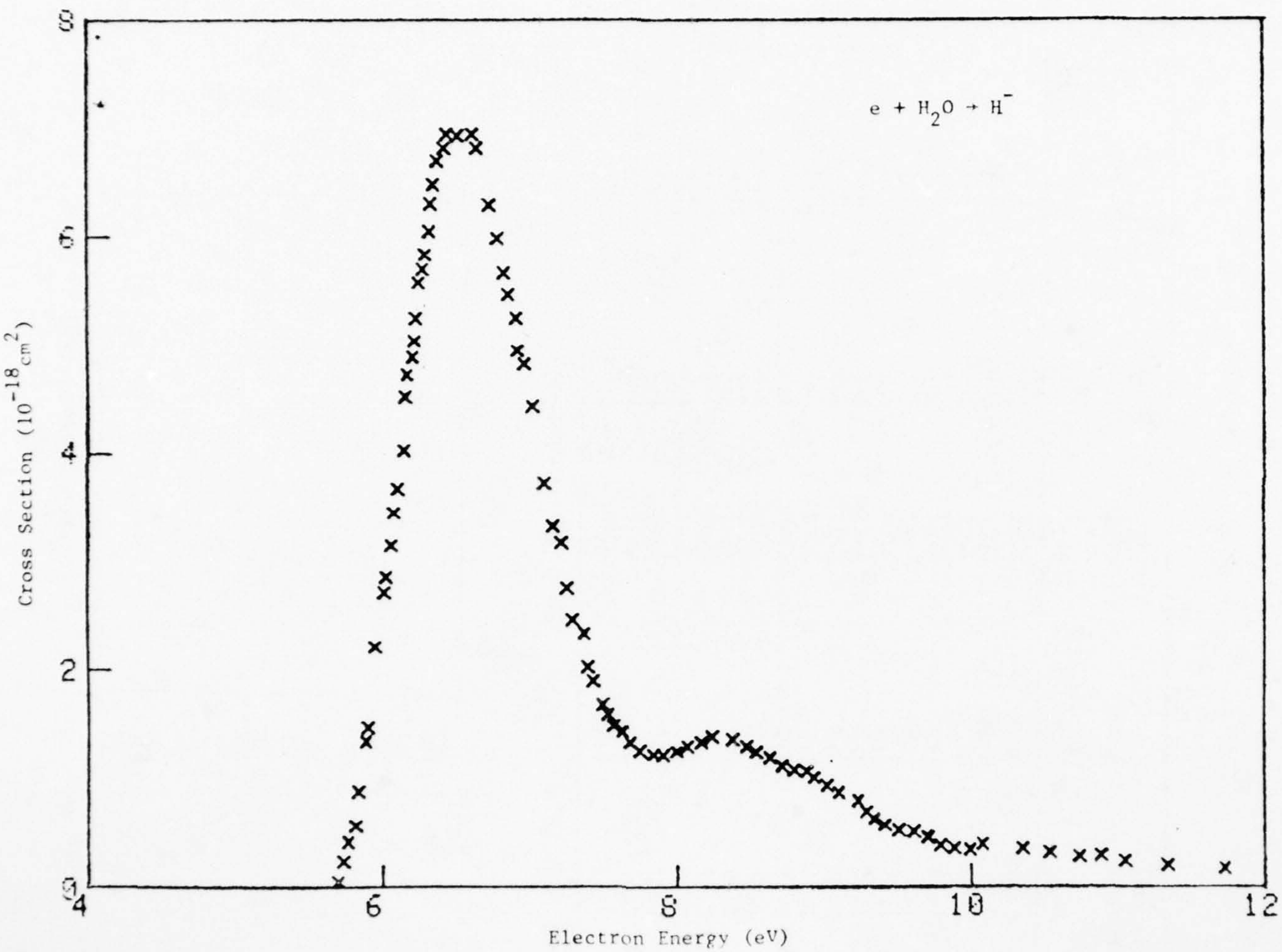
Tabular Data C-6.23b. Cross sections for dissociative attachment of electrons to H_2O.

$$e + H_2O \rightarrow H^-$$

Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$	Electron Energy eV	Cross Section $10^{-18}cm^2$
5.70	0.0451	6.64	6.82	8.48	1.28
5.73	0.229	6.73	6.30	8.54	1.23
5.76	0.407	6.78	6.00	8.63	1.18
5.81	0.559	6.83	5.67	8.72	1.10
5.84	0.873	6.86	5.47	8.80	1.07
5.89	1.33	6.91	5.25	8.89	1.05
5.90	1.46	6.92	4.95	8.94	0.996
5.95	2.20	6.97	4.83	9.03	0.925
6.01	2.71	7.03	4.43	9.11	0.858
6.02	2.84	7.11	3.71	9.24	0.779
6.06	3.13	7.16	3.31	9.30	0.687
6.08	3.44	7.22	3.16	9.35	0.614
6.11	3.66	7.26	2.74	9.42	0.559
6.14	4.02	7.29	2.45	9.51	0.514
6.15	4.51	7.37	2.32	9.61	0.495
6.17	4.73	7.40	2.01	9.70	0.449
6.20	4.89	7.44	1.89	9.70	0.449
6.21	5.04	7.50	1.66	9.79	0.373
6.23	5.26	7.54	1.57	9.88	0.341
6.25	5.58	7.58	1.48	9.99	0.331
6.28	5.71	7.64	1.42	10.1	0.384
6.29	5.85	7.69	1.32	10.3	0.344
6.32	6.06	7.75	1.24	10.5	0.312
6.33	6.32	7.85	1.21	10.7	0.274
6.34	6.49	7.91	1.21	10.9	0.286
6.38	6.71	8.01	1.24	11.1	0.230
6.42	6.83	8.08	1.28	11.3	0.191
6.43	6.95	8.17	1.31	11.7	0.169
6.52	6.94	8.25	1.37		
6.62	6.95	8.38	1.34		

Cont. Next Column   Cont. Next Column

Reference: R. N. Crompton and L. G. Christophorou, Phys. Rev. 154, 110 (1967)



Graphical Data C-6.23b. Cross sections for dissociative attachment of electrons to H_2O (Concluded).

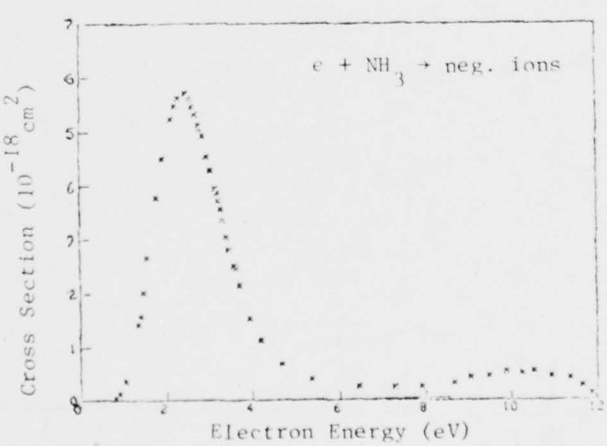
Tabular and Graphical Data C-6.24. Cross sections for dissociative attachment of electrons to NH_3.

$e + NH_3 \rightarrow$ negative ions

Electron Energy (eV)	Cross Section (10^{-18} cm^2)	Electron Energy (eV)	Cross Section (10^{-18} cm^2)	Electron Energy (eV)	Cross Section (10^{-18} cm^2)
0.795	0.047	2.79	5.1	5.37	0.39
0.893	0.11	2.87	4.9	6.46	0.26
1.05	0.36	2.95	4.6	7.29	0.24
1.33	1.4	3.05	4.3	7.92	0.25
1.39	1.6	3.13	3.9	8.67	0.32
1.45	2.0	3.18	3.9	9.06	0.42
1.54	2.7	3.21	3.7	9.48	0.45
1.78	3.8	3.27	3.6	9.88	0.54
1.92	4.5	3.29	3.4	10.3	0.51
2.11	5.2	3.40	3.0	10.5	0.55
2.21	5.5	3.46	2.8	10.9	0.46
2.29	5.6	3.57	2.5	11.4	0.41
2.47	5.7	3.62	2.5	11.7	0.28
2.55	5.6	3.71	2.1	11.9	0.12
2.61	5.5	3.94	1.5	12.0	0.020
2.67	5.3	4.21	1.1		
2.76	5.1	4.68	0.68		

Cont. Next Column

Cont. Next Column



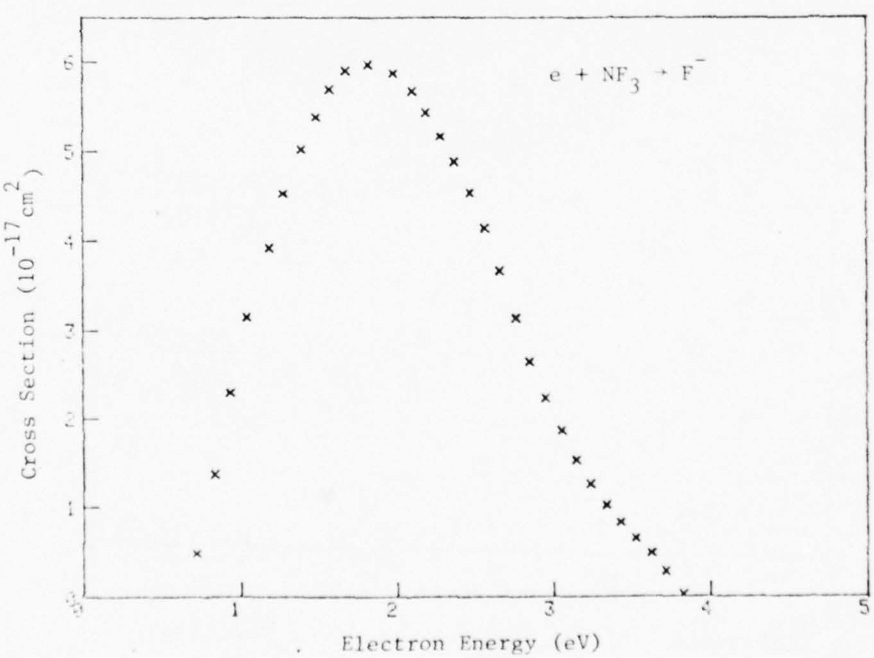
Reference: R. N. Compton, J. A. Stockdale and P. W. Reinhardt, Phys. Rev. 180, 111 (1969)

Tabular and Graphical Data C-6.25a. Cross sections for dissociative attachment of electrons to NF_3.

a. $e + NF_3 \rightarrow F^-$

Electron Energy eV	Cross Section $10^{-17} cm^2$	Electron Energy eV	Cross Section $10^{-17} cm^2$	Electron Energy eV	Cross Section $10^{-17} cm^2$
0.714	0.483	1.98	5.88	3.05	1.86
0.832	1.37	2.10	5.68	3.15	1.53
0.935	2.30	2.19	5.44	3.24	1.26
1.04	3.16	2.28	5.18	3.34	1.02
1.19	3.93	2.37	4.89	3.43	0.828
1.28	4.54	2.47	4.55	3.52	0.651
1.40	5.03	2.57	4.15	3.63	0.482
1.49	5.39	2.66	3.67	3.72	0.278
1.58	5.70	2.76	3.15	3.82	0.0206
1.68	5.91	2.85	2.64		
1.82	5.98	2.96	2.23		

Cont. Next Column   Cont. Next Column



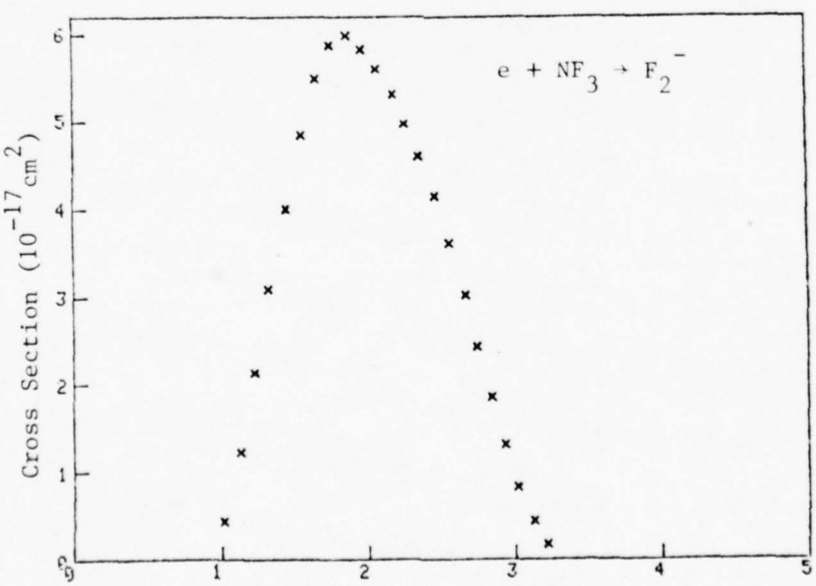
Reference: P. W. Harland and J. L. Franklin, J. Chem. Phys. 61, 1621 (1974)

Tabular and Graphical Data C-6.25b. Cross sections for dissociative attachment of electrons to NF_3.

b. $e + NF_3 \rightarrow F_2^-$

Electron Energy eV	Cross Section $10^{-17}cm^2$	Electron Energy eV	Cross Section $10^{-17}cm^2$
1.01	0.437	2.26	4.98
1.13	1.23	2.35	4.61
1.23	2.14	2.46	4.15
1.32	3.10	2.56	3.61
1.45	4.01	2.67	3.03
1.55	4.85	2.74	2.43
1.65	5.50	2.84	1.85
1.75	5.89	2.93	1.31
1.87	6.00	3.01	0.824
1.96	5.83	3.12	0.439
2.07	5.60	3.22	0.169
2.18	5.32		

Cont. Next Column



Reference: P. W. Harland and J. L. Franklin, J. Chem. Phys. 61, 1621 (1974)

Tabular Data C-6.25. Cross sections for dissociative attachment of electrons to NF_3.

c. $e + NF_3 \rightarrow NF_2^-$

Electron Energy eV	Cross Section $10^{-17}cm^2$	Electron Energy eV	Cross Section $10^{-17}cm^2$
0.997	0.361	1.98	5.84
1.12	1.49	2.08	5.49
1.23	2.64	2.17	4.87
1.37	3.73	2.26	4.00
1.48	4.63	2.34	2.90
1.58	5.30	2.43	1.67
1.67	5.71	2.53	0.480
1.77	5.92		
1.89	5.99		

Cont. Next Column

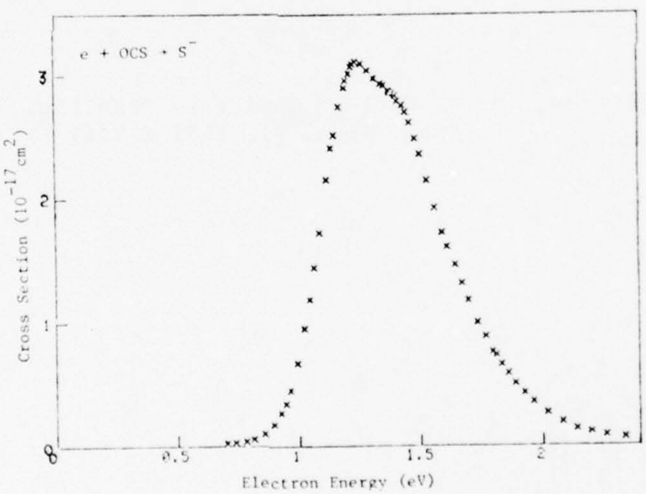
Reference: P. W. Harland and J. L. Franklin, J. Chem. Phys. 61, 1621 (1974)

Tabular and Graphical Data C-6.26a. Cross sections for dissociative attachment of electrons to OCS to form S^-.

a. $e + OCS \rightarrow S^-$

Electron Energy (eV)	Cross Section (10^{-17} cm^2)	Electron Energy (eV)	Cross Section (10^{-17} cm^2)	Electron Energy (eV)	Cross Section (10^{-17} cm^2)
0.700	0.0216	1.23	3.10	1.67	1.31
0.735	0.0308	1.24	3.12	1.70	1.17
0.779	0.0397	1.26	3.10	1.74	0.993
0.811	0.0569	1.29	3.04	1.77	0.877
0.854	0.102	1.32	2.98	1.80	0.752
0.894	0.176	1.34	2.93	1.81	0.730
0.923	0.269	1.36	2.92	1.83	0.653
0.944	0.341	1.38	2.88	1.86	0.577
0.962	0.449	1.38	2.86	1.89	0.500
0.992	0.665	1.39	2.86	1.93	0.423
1.02	0.948	1.40	2.84	1.96	0.354
1.05	1.18	1.41	2.80	2.02	0.264
1.07	1.44	1.43	2.76	2.08	0.189
1.09	1.73	1.44	2.71	2.14	0.137
1.12	2.16	1.46	2.62	2.20	0.109
1.14	2.41	1.48	2.49	2.26	0.0850
1.15	2.52	1.50	2.36	2.34	0.0593
1.17	2.75	1.53	2.15		
1.19	2.90	1.56	1.93		
1.20	2.96	1.59	1.72		
1.21	3.02	1.61	1.60		
1.22	3.08	1.64	1.45		

Cont. Next Column Cont. Next Column



Reference: J. P. Ziesel, G. J. Schulz, and J. Milhaud, J. Chem. Phys. 62, 1936 (1975)

Tabular and Graphical Data C-6.26a. Cross sections for dissociative attachment of electrons to OCS to form S^- (Continued).

$e + OCS \rightarrow S^-$

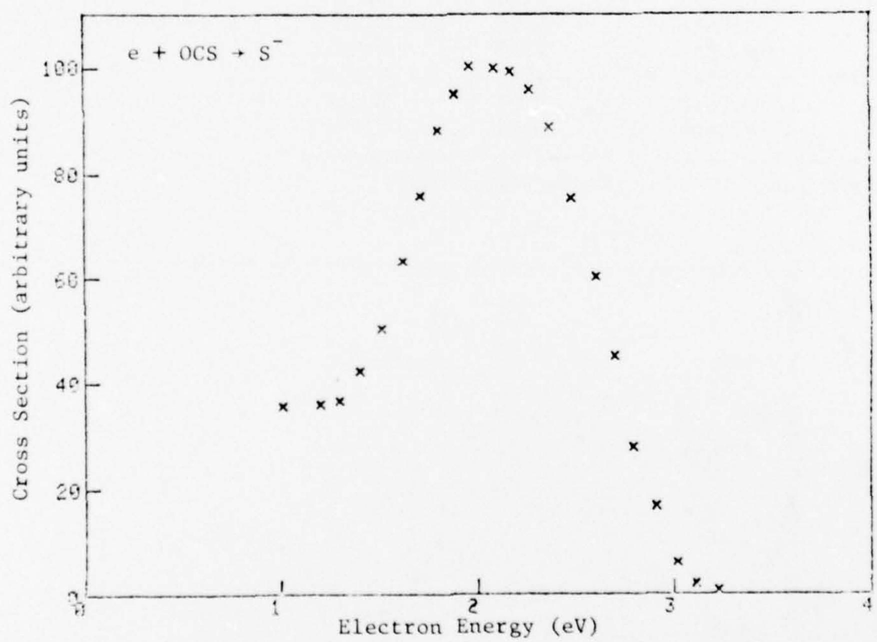
Electron Energy eV	Cross Section arbitrary
1.01	35.6
1.20	35.9
1.30	36.7
1.40	42.3
1.51	50.3
1.62	63.3
1.71	75.8
1.80	88.5

Cont. Next Column

Electron Energy eV	Cross Section arbitrary
1.89	95.0
1.97	100
2.09	100
2.17	99.3
2.27	96.0
2.37	89.0
2.48	75.3
2.61	60.2

Cont. Next Column

Electron Energy eV	Cross Section arbitrary
2.70	45.0
2.79	27.7
2.91	16.5
3.02	5.91
3.11	1.86
3.23	0.757

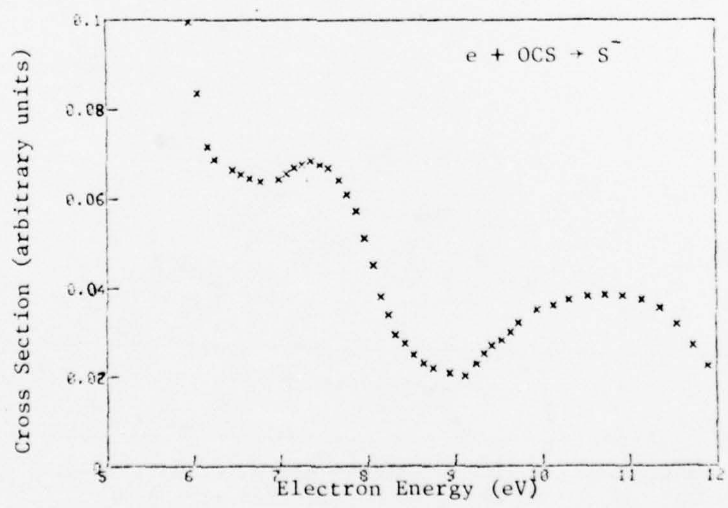


Reference: K. A. G. MacNeil and J. C. J. Thynne, J. Phys. Chem. 73, 2960 (1969)

Tabular and Graphical Data C-6.26a. Cross sections for dissociative attachment of electrons to OCS to form S^- (Concluded).

$e + OCS \rightarrow S^-$

Electron Energy eV	Cross Section arbitrary	Electron Energy eV	Cross Section arbitrary	Electron Energy eV	Cross Section arbitrary
5.95	0.0995	7.86	0.0572	9.73	0.0320
6.04	0.0835	7.95	0.0511	9.94	0.0350
6.16	0.0717	8.06	0.0451	10.1	0.0361
6.23	0.0689	8.14	0.0381	10.3	0.0373
6.45	0.0663	8.24	0.0340	10.5	0.0382
6.54	0.0654	8.31	0.0295	10.7	0.0384
6.64	0.0645	8.42	0.0274	10.9	0.0383
6.77	0.0639	8.53	0.0248	11.1	0.0373
6.98	0.0644	8.64	0.0229	11.3	0.0355
7.06	0.0656	8.75	0.0218	11.5	0.0318
7.16	0.0669	8.94	0.0207	11.7	0.0271
7.24	0.0676	9.12	0.0200	11.9	0.0224
7.34	0.0684	9.25	0.0228		
7.45	0.0676	9.33	0.0252		
7.55	0.0669	9.42	0.0268		
7.67	0.0642	9.53	0.0281		
7.76	0.0609	9.64	0.0299		
Cont. Next Column		Cont. Next Column			



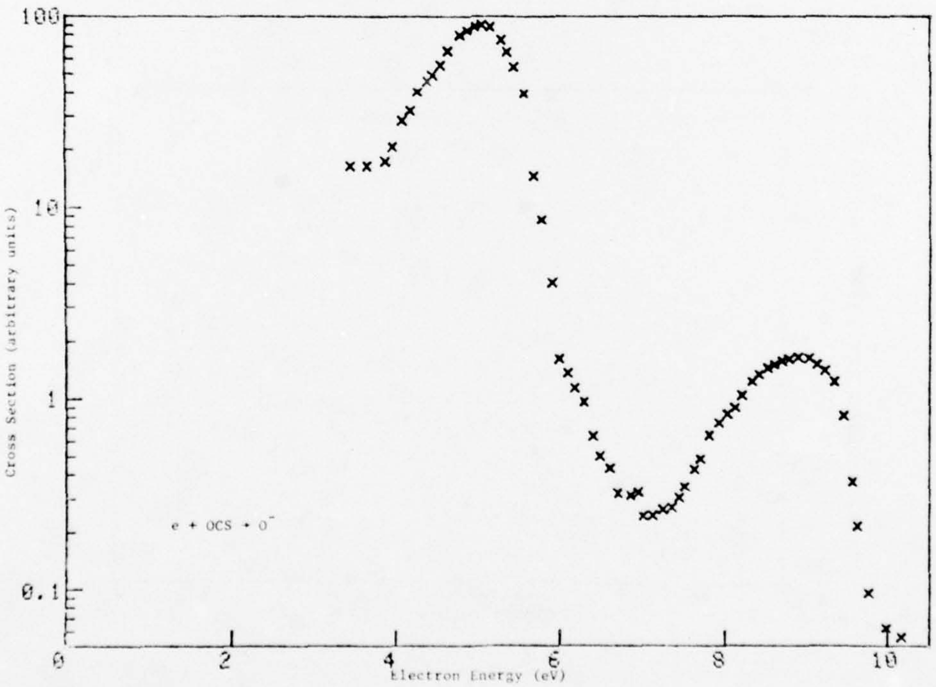
Reference: K. A. G. MacNeil and J. C. J. Thynne, J. Phys. Chem. 73, 2960 (1969)

Tabular and Graphical Data C-6.26b. Cross sections for dissociative attachment of electrons to OCS.

$e + OCS \rightarrow O^-$

Electron Energy eV	Cross Section arbitrary	Electron Energy eV	Cross Section arbitrary	Electron Energy eV	Cross Section arbitrary
3.45	16.4	6.00	1.59	8.35	1.21
3.66	16.4	6.11	1.37	8.43	1.33
3.89	17.7	6.19	1.12	8.54	1.44
3.98	20.5	6.31	0.942	8.62	1.51
4.09	28.4	6.41	0.623	8.72	1.55
4.19	32.1	6.50	0.494	8.80	1.59
4.27	40.2	6.62	0.425	8.91	1.63
4.39	45.5	6.71	0.315	9.04	1.63
4.46	49.0	6.87	0.308	9.13	1.51
4.57	55.5	6.96	0.316	9.23	1.40
4.66	66.0	7.02	0.240	9.35	1.24
4.80	80.5	7.13	0.240	9.45	0.812
4.89	84.6	7.26	0.259	9.57	0.366
4.98	88.9	7.37	0.265	9.63	0.212
5.06	91.2	7.45	0.300	9.76	0.0934
5.16	88.9	7.53	0.340	9.88	0.0612
5.30	76.6	7.65	0.415	9.99	0.0454
5.37	66.0	7.73	0.482	10.2	0.0554
5.46	54.1	7.83	0.633		
5.57	39.2	7.94	0.735		
5.70	14.5	8.04	0.812		
5.80	8.60	8.14	0.897		
5.91	4.02	8.22	1.04		

Cont. Next Column   Cont. Next Column



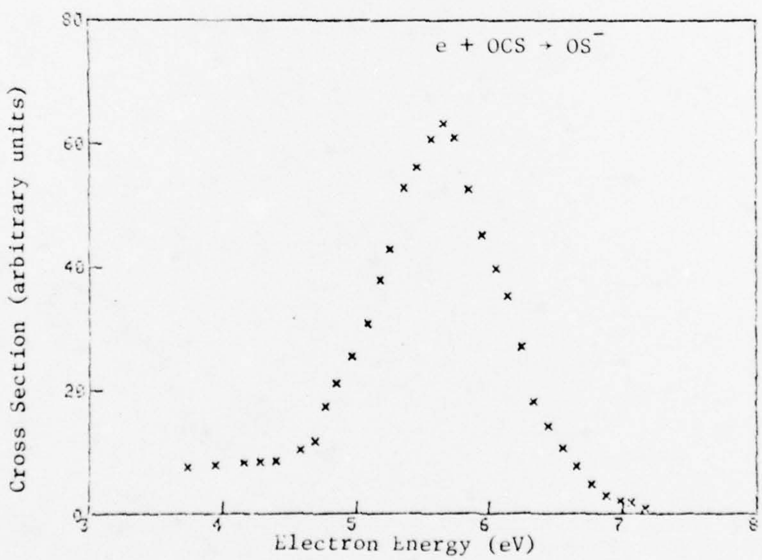
Reference: K. A. G. MacNeil and J. C. J. Thynne, J. Phys. Chem. 73, 2960 (1969)

Tabular and Graphical Data C-6.26c. Cross sections for dissociative attachment of electrons to OCS.

$$e + OCS \rightarrow OS^-$$

Electron Energy eV	Cross Section arbitrary	Electron Energy eV	Cross Section arbitrary	Electron Energy eV	Cross Section arbitrary
3.74	7.53	5.18	37.9	6.24	27.1
3.95	7.92	5.25	42.8	6.33	18.1
4.16	8.28	5.36	52.8	6.44	14.2
4.28	8.41	5.46	56.1	6.55	10.7
4.40	8.56	5.57	60.9	6.66	7.73
4.58	10.4	5.66	63.3	6.76	4.79
4.69	11.8	5.75	61.0	6.88	2.96
4.77	17.4	5.85	52.4	6.98	2.09
4.85	21.1	5.95	45.0	7.06	1.82
4.97	25.4	6.05	39.7	7.17	0.960
5.09	30.8	6.13	35.2		

Cont. Next Column   Cont. Next Column



Reference: K. A. G. MacNeil and J. C. J. Thynne, J. Phys. Chem. 73, 2960 (1969)

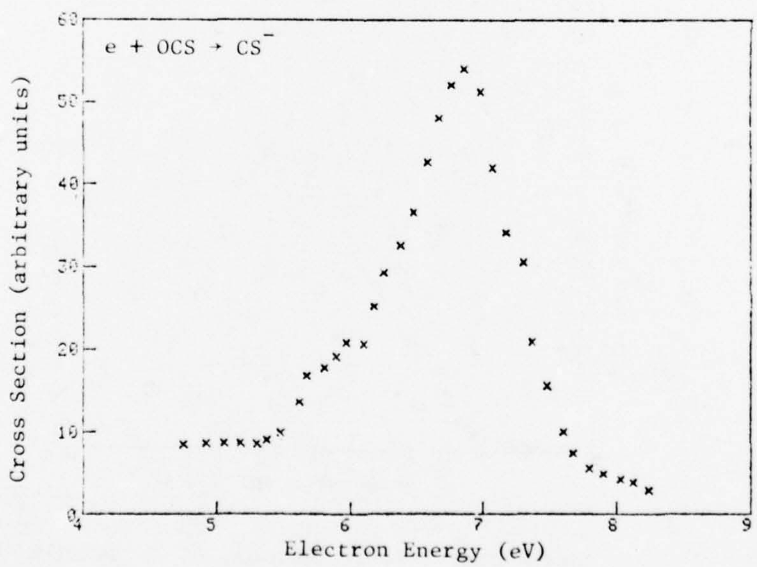
Tabular and Graphical Data C-6.26d. Cross sections for dissociative attachment of electrons to OCS.

$e + OCS \rightarrow CS^-$

Electron Energy eV	Cross Section arbitrary	Electron Energy eV	Cross Section arbitrary	Electron Energy eV	Cross Section arbitrary
4.75	8.44	6.10	20.7	7.31	30.5
4.92	8.63	6.18	25.2	7.37	20.8
5.05	8.62	6.25	29.3	7.48	15.6
5.18	8.61	6.38	32.5	7.60	9.94
5.30	8.51	6.48	36.6	7.67	7.41
5.38	9.05	6.58	42.8	7.79	5.58
5.48	9.92	6.67	48.1	7.90	4.88
5.62	13.7	6.76	52.2	8.03	4.26
5.67	16.8	6.86	54.2	8.12	3.87
5.81	17.8	6.98	51.4	8.24	2.89
5.89	19.1	7.07	42.1		
5.97	20.9	7.17	34.1		

Cont. Next Column

Cont. Next Column



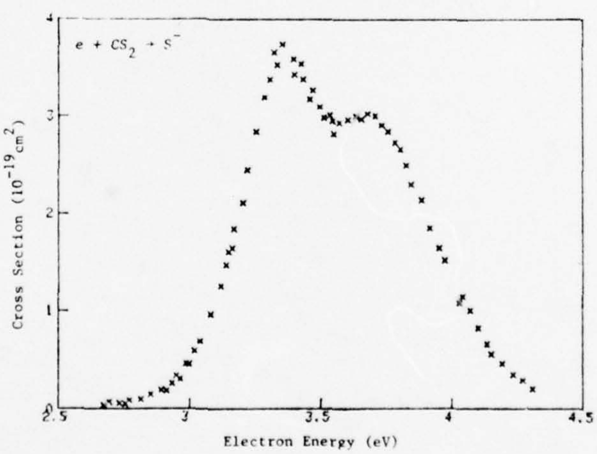
Reference: K. A. G. MacNeil and J. C. J Thynne, J. Phys. Chem. 73, 2960 (1969)

Tabular and Graphical Data C-6.27a. Cross sections for dissociative attachment of electrons to CS_2 to form S^-.

$e + CS_2 \rightarrow S^-$

Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$
2.67	0.0357	3.29	3.20	3.78	2.73
2.69	0.0613	3.31	3.38	3.80	2.66
2.73	0.0483	3.32	3.66	3.82	2.49
2.75	0.0428	3.34	3.53	3.85	2.29
2.77	0.0822	3.35	3.75	3.89	2.13
2.82	0.0889	3.40	3.59	3.92	1.84
2.85	0.140	3.40	3.43	3.95	1.64
2.89	0.186	3.43	3.54	3.97	1.51
2.91	0.180	3.43	3.38	4.04	1.14
2.93	0.254	3.47	3.26	4.03	1.08
2.95	0.337	3.46	3.17	4.07	0.999
2.96	0.303	3.50	3.09	4.10	0.820
2.99	0.456	3.51	2.99	4.14	0.651
3.00	0.446	3.54	3.01	4.15	0.549
3.02	0.586	3.54	2.95	4.19	0.455
3.04	0.683	3.55	2.82	4.23	0.344
3.08	0.958	3.57	2.93	4.27	0.285
3.12	1.25	3.60	2.96	4.31	0.200
3.14	1.47	3.63	3.00		
3.15	1.60	3.64	3.00		
3.16	1.64	3.66	2.97		
3.17	1.84	3.68	3.02		
3.21	2.10	3.71	3.00		
3.22	2.45	3.73	2.91		
3.25	2.84	3.75	2.84		

Cont. Next Column   Cont. Next Column

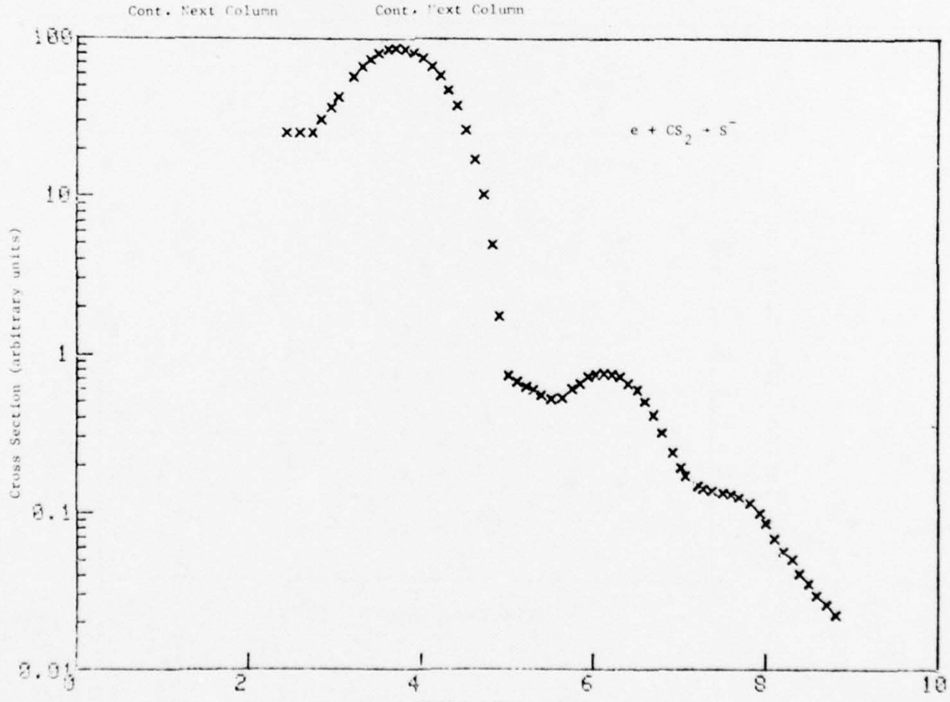


Reference: J. P. Ziesel, G. J. Schulz and J. Milhaud, J. Chem. Phys. 62, 1936 (1965)

Tabular and Graphical Data C-6.27a. Cross sections for dissociative attachment of electrons to CS_2 (Concluded).

$e + CS_2 \rightarrow S^-$

Electron Energy eV	Cross Section arbitrary	Electron Energy eV	Cross Section arbitrary	Electron Energy eV	Cross Section arbitrary
2.43	25.4	5.11	0.672	7.60	0.128
2.58	25.4	5.21	0.625	7.69	0.125
2.73	25.4	5.30	0.595	7.82	0.113
2.83	30.8	5.39	0.554	7.92	0.0980
2.94	36.4	5.51	0.515	8.00	0.0848
3.02	43.1	5.63	0.528	8.10	0.0683
3.21	58.9	5.75	0.595	8.21	0.0564
3.30	66.4	5.85	0.656	8.31	0.0500
3.40	74.9	5.94	0.722	8.39	0.0402
3.49	82.5	6.02	0.739	8.50	0.0357
3.60	86.6	6.12	0.757	8.59	0.0294
3.69	88.7	6.22	0.739	8.70	0.0255
3.80	86.6	6.31	0.722	8.80	0.0221
3.90	82.5	6.40	0.640		
4.01	76.8	6.51	0.595		
4.10	66.4	6.59	0.503		
4.20	58.9	6.70	0.415		
4.30	47.4	6.80	0.319		
4.40	37.3	6.92	0.239		
4.50	26.6	7.02	0.192		
4.61	17.3	7.07	0.170		
4.71	10.2	7.21	0.144		
4.82	4.95	7.27	0.141		
4.89	1.72	7.38	0.137		
5.01	0.722	7.51	0.131		
Cont. Next Column		Cont. Next Column			



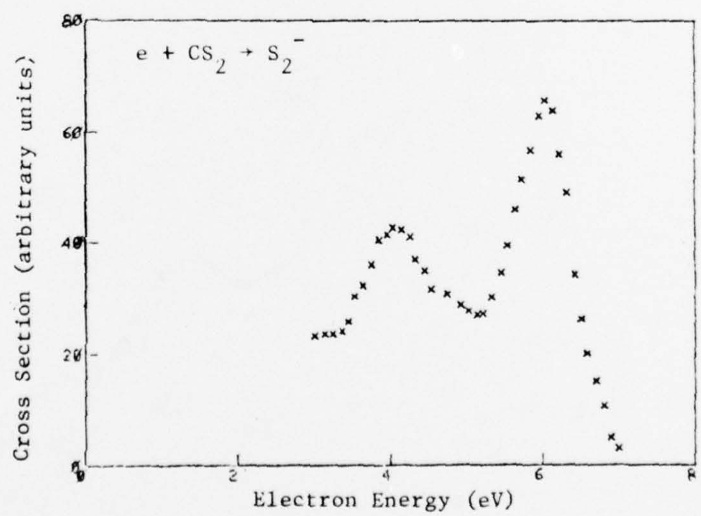
Reference: K. A. G. MacNeil and J. C. J. Thynne, J. Phys. Chem. 73, 2960 (1969)

Tabular and Graphical Data C-6.27b. Cross sections for dissociative attachment of electrons to CS_2.

$$e + CS_2 \rightarrow S_2^-$$

Electron Energy eV	Cross Section arbitrary	Electron Energy eV	Cross Section arbitrary	Electron Energy eV	Cross Section arbitrary
3.00	23.5	4.33	37.0	5.84	56.9
3.13	23.7	4.44	35.1	5.95	63.2
3.23	23.7	4.53	31.8	6.02	65.9
3.35	24.2	4.74	30.9	6.13	64.0
3.45	25.9	4.92	29.0	6.22	56.2
3.53	30.4	5.03	27.9	6.33	49.1
3.64	32.4	5.14	27.2	6.42	34.3
3.75	36.1	5.21	27.4	6.50	26.3
3.85	40.4	5.34	30.3	6.58	20.1
3.95	41.4	5.46	34.7	6.69	15.1
4.03	42.6	5.54	39.5	6.80	10.7
4.14	42.2	5.64	45.9	6.89	4.83
4.25	41.0	5.73	51.4	6.99	2.92

Cont. Next Column Cont. Next Column



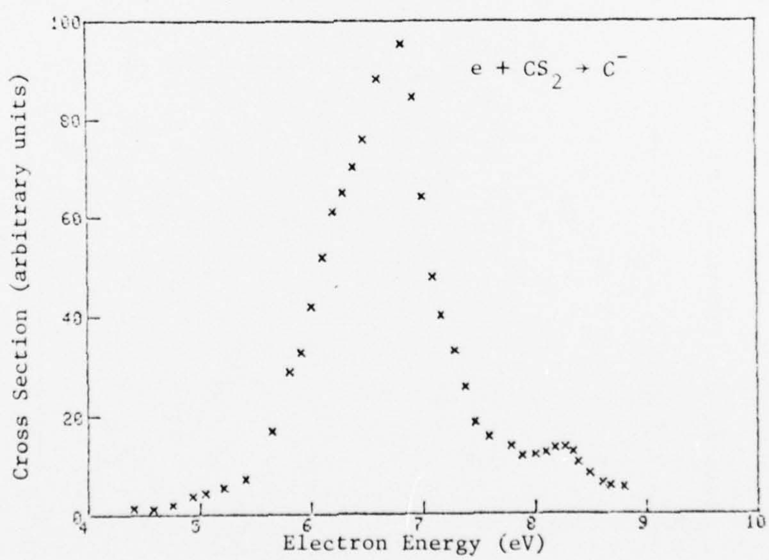
Reference: K. A G. MacNeil and J. C. J. Thynne, J. Phys. Chem. 73, 2960 (1969)

Tabular and Graphical Data C-6.27c. Cross sections for dissociative attachment of electrons to CS_2.

$$e + CS_2 \rightarrow C^-$$

Electron Energy eV	Cross Section arbitrary	Electron Energy eV	Cross Section arbitrary	Electron Energy eV	Cross Section arbitrary
4.40	1.26	6.29	64.8	7.79	13.6
4.58	1.17	6.38	70.3	7.88	11.7
4.75	2.06	6.48	75.9	8.00	11.9
4.93	3.90	6.60	88.2	8.09	12.4
5.04	4.35	6.83	95.4	8.18	13.3
5.21	5.39	6.92	84.5	8.27	13.4
5.41	7.19	7.01	64.1	8.34	12.5
5.64	16.8	7.10	47.7	8.38	10.4
5.81	28.9	7.17	40.0	8.49	8.15
5.91	32.7	7.29	32.9	8.60	6.30
6.01	42.0	7.38	25.6	8.68	5.69
6.11	51.8	7.47	18.4	8.80	5.33
6.21	61.1	7.58	15.5		

Cont. Next Column Cont. Next Column



Reference: K. A. G. MacNeil and J. C. J. Thynne, J. Phys. Chem. 73, 2960 (1969)

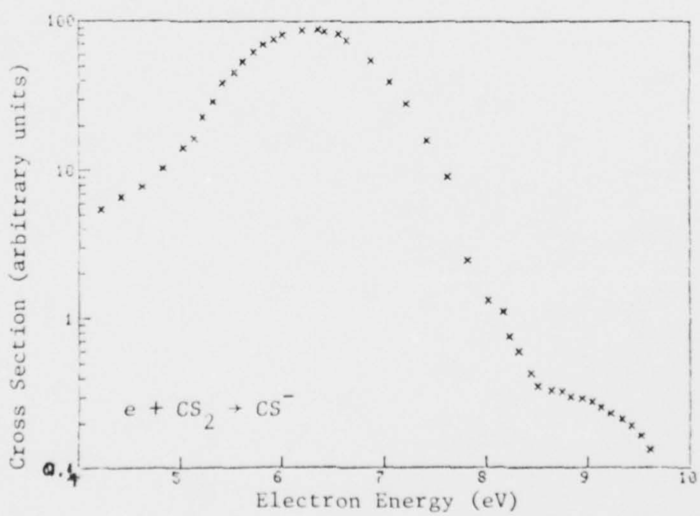
Tabular and Graphical Data C-6.27d. Cross sections for dissociative attachment of electrons to CS_2.

$$e + CS_2 \rightarrow CS^-$$

Electron Energy eV	Cross Section arbitrary	Electron Energy eV	Cross Section arbitrary	Electron Energy eV	Cross Section arbitrary
4.21	5.37	6.20	86.8	8.44	0.423
4.41	6.66	6.35	89.2	8.51	0.351
4.62	7.82	6.42	86.8	8.64	0.324
4.82	10.2	6.56	82.3	8.75	0.315
5.03	14.1	6.64	73.9	8.83	0.299
5.13	16.5	6.87	55.1	8.95	0.291
5.22	22.8	7.05	40.0	9.04	0.276
5.32	29.0	7.22	28.2	9.13	0.255
5.41	38.9	7.42	16.1	9.22	0.229
5.53	45.7	7.63	8.93	9.34	0.211
5.61	53.6	7.82	2.47	9.43	0.195
5.72	63.0	8.02	1.30	9.52	0.166
5.81	70.1	8.17	1.08	9.62	0.130
5.92	75.9	8.23	0.742		
6.00	82.3	8.32	0.599		

Cont. Next Column

Cont. Next Column

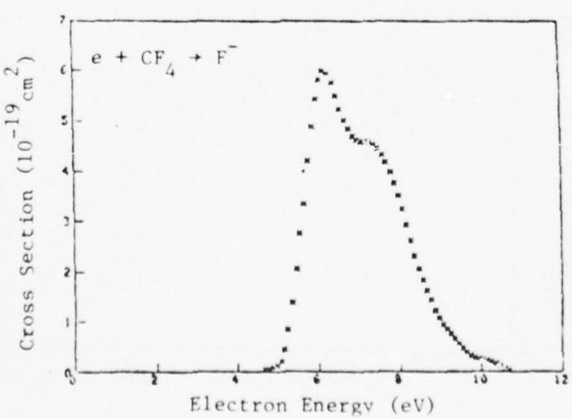


Reference: K. A. G. MacNeil and J. C. J. Thynne, J. Phys. Chem. 73, 2960 (1969)

Tabular and Graphical Data C-6.28a. Cross sections for dissociative attachment of electrons to CF_4.

$e + CF_4 \rightarrow F^-$

Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$
4.66	0.0572	6.77	4.84	8.86	1.22
4.76	0.0609	6.88	4.69	8.96	1.07
4.86	0.0851	6.97	4.62	9.07	0.940
4.96	0.119	7.06	4.58	9.16	0.849
5.06	0.206	7.17	4.58	9.26	0.756
5.15	0.432	7.27	4.58	9.35	0.653
5.24	0.826	7.37	4.54	9.45	0.555
5.35	1.38	7.48	4.45	9.56	0.462
5.46	2.06	7.58	4.32	9.65	0.388
5.55	2.77	7.67	4.18	9.75	0.319
5.66	3.34	7.78	3.98	9.84	0.275
5.77	4.21	7.87	3.77	9.94	0.259
5.88	4.88	7.97	3.51	10.1	0.254
5.98	5.43	8.06	3.24	10.2	0.235
6.07	5.82	8.16	2.92	10.2	0.202
6.16	5.99	8.28	2.61	10.4	0.159
6.27	5.94	8.36	2.31	10.5	0.119
6.38	5.76	8.47	2.06	10.6	0.0634
6.47	5.49	8.58	1.82	10.7	0.0255
6.56	5.23	8.67	1.62		
6.68	5.01	8.76	1.43		
Cont. Next Column		Cont. Next Column			



Reference: P. W Harland and J. L. Franklin, J. Chem. Phys. 61, 1621 (1974)

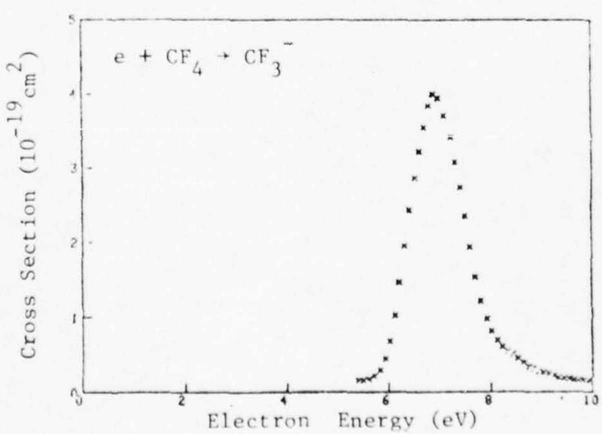
Tabular and Graphical Data C-6.28b. Cross sections for dissociative attachment of electrons to CF_4.

$e + CF_4 \rightarrow CF_3^-$

Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$	Electron Energy eV	Cross Section $10^{-19} cm^2$
5.40	0.162	6.99	3.94	8.63	0.388
5.50	0.165	7.10	3.72	8.74	0.339
5.60	0.177	7.21	3.42	8.83	0.314
5.70	0.214	7.30	3.08	8.92	0.274
5.82	0.293	7.40	2.74	9.02	0.263
5.92	0.453	7.50	2.34	9.12	0.247
6.01	0.679	7.59	1.93	9.23	0.227
6.11	1.02	7.71	1.53	9.32	0.194
6.20	1.46	7.80	1.21	9.43	0.184
6.29	1.94	7.91	0.979	9.53	0.175
6.40	2.44	8.01	0.806	9.63	0.162
6.50	2.87	8.12	0.687	9.72	0.158
6.60	3.22	8.22	0.603	9.82	0.152
6.70	3.56	8.32	0.534	9.92	0.142
6.80	3.85	8.42	0.502	10.0	0.140
6.89	4.00	8.52	0.446		

Cont. Next Column

Cont. Next Column



Reference: P. W. Harland and J. L. Franklin, J. Chem. Phys. 61, 1621 (1974)

DISTRIBUTION

	No. of Copies
School of Physics Georgia Institute of Technology Attn: Dr. E. W. McDaniel	50
K. J. McCann	10
Dr. F. L. Eisele	10
E. W. Thomas	10
Dr. W. M. Pope	10
Dr. M. R. Flannery	10
Atlanta, Georgia 30332	
Joint Institute for Laboratory Astrophysics University of Colorado Attn: J. W. Gallagher	10
J. R. Rumble	10
E. C. Beaty	10
Boulder, Colorado 80302	
Eckerd College Attn: Dr. H. W. Ellis	10
St. Petersburg, Florida 33733	
Physics Department Georgia State University Attn: S. T. Manson	10
Atlanta, Georgia 30303	
Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
Director Ballistic Missile Defense Advanced Technology Center Attn: ATC, Mr. J. D. Carlson	1
ATC-O, Mr. W. Davies	1
Mr. G. Sanmann	1
Mr. J. Hagefstration	1
-T, Dr. E. Wilkinson	1
-R, Mr. Don Schenk	1
P. O. Box 1500 Huntsville, Alabama 35807	
Defense Advanced Research Project 1400 Wilson Boulevard Attn: Director, Laser Division	1
Arlington, Virginia 22209	

	No. of Copies
Lawrence Livermore Laboratory	
P. O. Box 808	
Attn: Dr. Joe Fleck	1
Dr. John Emmet	1
Livermore, California 94550	
Los Alamos Scientific Laboratory	
P. O. Box 1663	
Attn: Dr. Keith Boyer (MS 550)	1
Los Alamos, New Mexico 87544	
Central Intelligence Agency	
Attn: Mr. Julian C. Nall (OSI/PSTD)	1
Washington, D.C. 20505	
US Army Research Office	
Attn: Dr. Robert Lontz	2
P. O. Box 12211	
Research Triangle Park, North Carolina 27709	
DRCPM-HEL, COL D. H. Lueders	1
HEL-T, Dr. C. J. Albers	1
DRSMI-LP, Mr. Voigt	1
DRDMI-T, Dr. Kobler	1
-H, Dr. Hallowes	1
-HS, Dr. Honeycutt	1
Mr. Cason	1
Dr. Roberts (Additional Distribution)	485
-NS	1
-TBD	3
-TI (Record Set)	1
(Reference Copy)	1